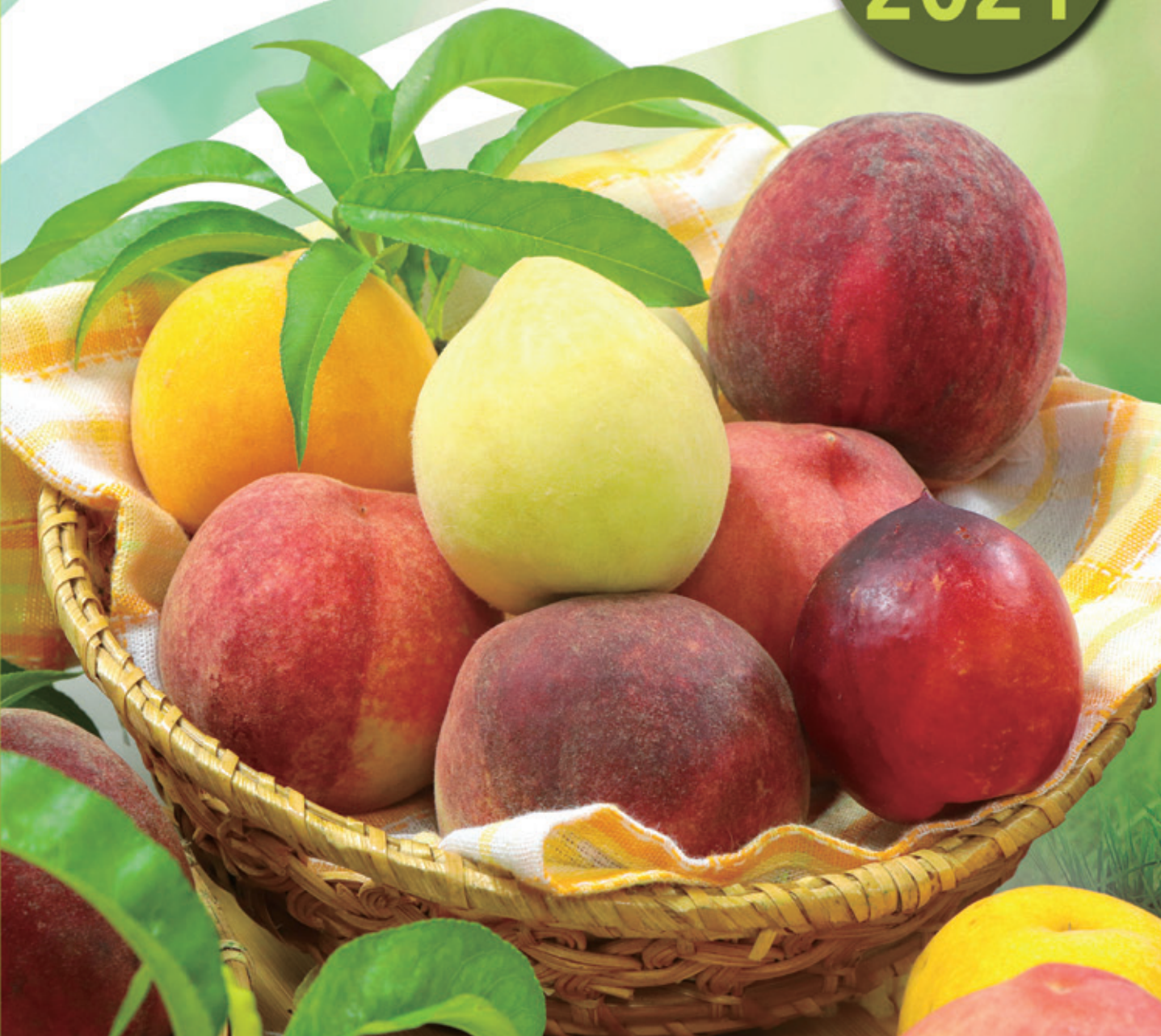
TARI
ANNUAL REPORT
2021





Taiwan Agricultural Research Institute

Published by Taiwan Agricultural Research Institute
189, Chung-Cheng Road, Wufeng Taichung City 41362 Taiwan R.O.C.
T +886 4 2330 2301
F +886 4 2333 8162
E mwf-doc@tari.gov.tw



https://www.tari.gov.tw/english/

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Editor Chang-Tsern Chen

Contributors Ming- Hsin Lai, Dong-Hong Wu, Charng-Pei Li, Guang-Jauh Shieh, Hung-Yu Dai, Da-Gin Lin, Chu-Chung Chen, Me-Chi Yao, Shu-Chen Chang, Jin-Hsing Huang, Yih-Juh Shiau, Chun-Che Huang, Wu-Huan Hsu, Hsiang-Wen Chiu, Che-Lun Huang, Shu-Fen Chang, Chen-Yu Lin, Yu-Shih Hsieh, Shu-Fen Shiau, Yu-Hsuan Yang, Chang-Tsern Chen

Cover photo TARI has released 10 varieties of low-chill peaches (100-180 CU) with low acidity, sweet taste, and attractive look.

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Foreword from the Director General

According to the IPCC's 6th Assessment Report (AR6) released in August 2021, climate change caused by human activities is intensifying, and as well affecting people's lives and natural ecology, agricultural production is feeling the strain. Taiwan Agricultural Research Institute (TARI) attached great importance to the topic of climate change very early and put it into research. In addition to actively constructing a screening platform for resistance to adversity, accelerating



the research and development capacity of adaptation technologies, and using agricultural weather information to enhance farmers' disaster prevention capabilities, TARI has also developed various carbon reduction and recycling technologies to reduce carbon dioxide and other greenhouse gas emissions.

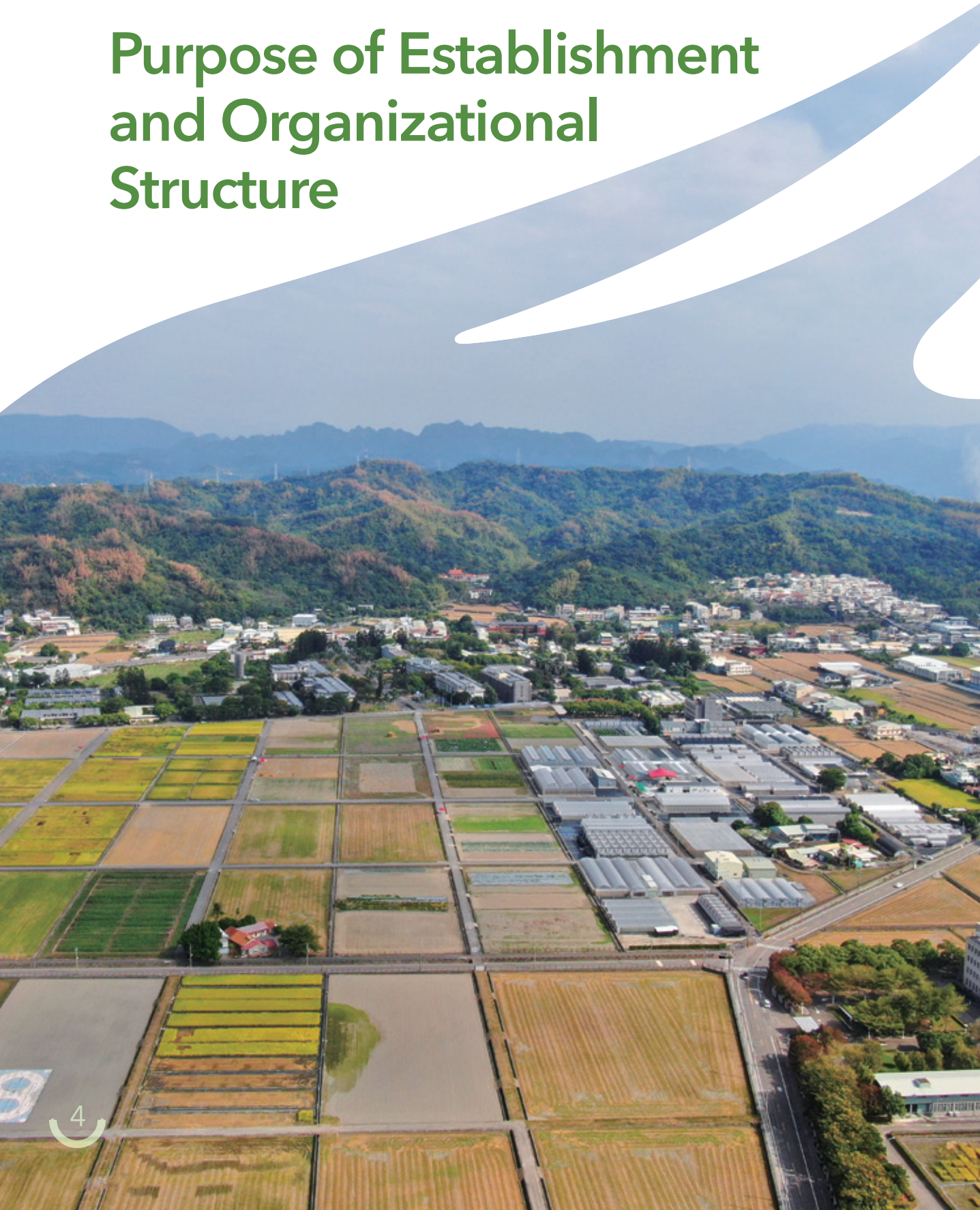
In 2021, TARI published important results relating to the adaption of climate change and net zero emissions, including Silage corn 'Tainung No. 8', a green-cut maize with early maturity, a long green retention period of the bottom leaves, and a high fresh grass yield, suitable for rotational areas of rice and upland crops in Yunlin-Chiayi-Tainan. Potato 'Tainung No. 4' has better tolerance than the current varieties 'Kennebec' and 'Atlantic'. Peanut 'Tainung No. 11' is suitable for mechanical harvesting as it remains upright and does not lodge easily, which also shows last longer oil stability and fewer odors during storage due to high oleic acid characteristics. The recycling technology for waste of mushroom bags has been developed, creating multiple new uses for recycling waste materials. Furthermore, by adopting an open architecture design for an agricultural wireless control system, traditional control equipment can be upgraded to an application under the Internet of Things. By applying protein-rich fermented soybean, the plant-based chicken essence, which is high in branched-chain amino acids, was created through fermentation, maturation and extraction. Besides, the ingredient is simple and has strong natural umami and mushroom flavor.

When faced with the challenges of climate change, COVID-19, sustainable development, net zero emissions and other important issues, Taiwan's agriculture needs to be stable. TARI will continue to develop new varieties, new technologies and new systems, improve the agricultural structure, help farmers and the agricultural industry be competitive, cultivate sustainable management capabilities, establish a green economy, shape the new agricultural power of the industry and improve agricultural marketing abilities.



Hsueh-Shih Lin Ph.D.

Purpose of Establishment and Organizational Structure





TARI, which was founded in1895, conducts research and development in science and technology for the agri-food industry. Based on the fundamental and applied scientific theories of agriculture and industrial demand, TARI has established itself as a pioneer of agricultural scientific research in Taiwan, a leader in agricultural R&D innovation and value addition, and a provider of comprehensive technological industrial solutions. Additionally, TARI has set itself the objective of increasing the effectiveness of scientific and technological R&D by comprehensive resource planning and the introduction of forward-thinking scientific research energy via R&D innovation. The three major goals of TARI are to enhance the effectiveness of R&D through resource coordination, to increase the energy of progressive research through R&D innovation, and to provide a model to cope with industrial demand through cross-disciplinary integration. The planning of the institute's present organizational structure is based on the main climatic zones, important crop development needs, and the field of agricultural research. Crop science, biotechnology, agricultural chemistry, plant pathology, applied zoology, agricultural engineering, agricultural economics, plant germplasm, farm management, and technical service are TARI's ten divisions, as well as two affiliated units, the Floriculture Research Center and the Guansi Experience Station. Additionally, it has two branches, the Fengshan Tropical Horticultural Experience Branch and the Chiayi Agricultural Experience Branch.

TARI employs experts in a broad range of agricultural science and technology domains. To advance Taiwan's basic agricultural research, it also focuses on applied scientific and technological research and development in addition to basic strategic plant research in areas like plant germplasms, molecular breeding, safety evaluation of genetically modified crops, biodiversity, investigation and analysis of agricultural geographic properties, crop physiology and stress, bioinformatics, classification and identification of insects and pathogenic microorganisms, etc.

The following research and development objectives have been developed with TARI's status as "the pioneer of agricultural R&D innovation and value addition" and "the provider of industrial comprehensive services" in mind: to promote innovative research and development of agricultural science and technology, implement achievements in value-added industrial services, increase the effectiveness of organizational resource management, respond to climate change, and strengthen international integration. TARI's vision includes:



Being the leader in agricultural R&D innovation and value addition

1. Crop production: to cope with the impact of climate change and improve the ability to withstand stress.

2. Interdisciplinary innovation in science and technology: to combine cross-industry and multidisciplinary resources in order to advance and innovate agricultural science and technology.

3. Safe agriculture: to sustain healthy and safe food production and to establish a high-quality production system.

4. Resource diversity: to preserve biodiversity and strengthen capability to conserve resources.

5. Environmental sustainability: to create a mechanism for recycling resources to enable sustainable agricultural development.

Being the provider of comprehensive technological industrial solutions

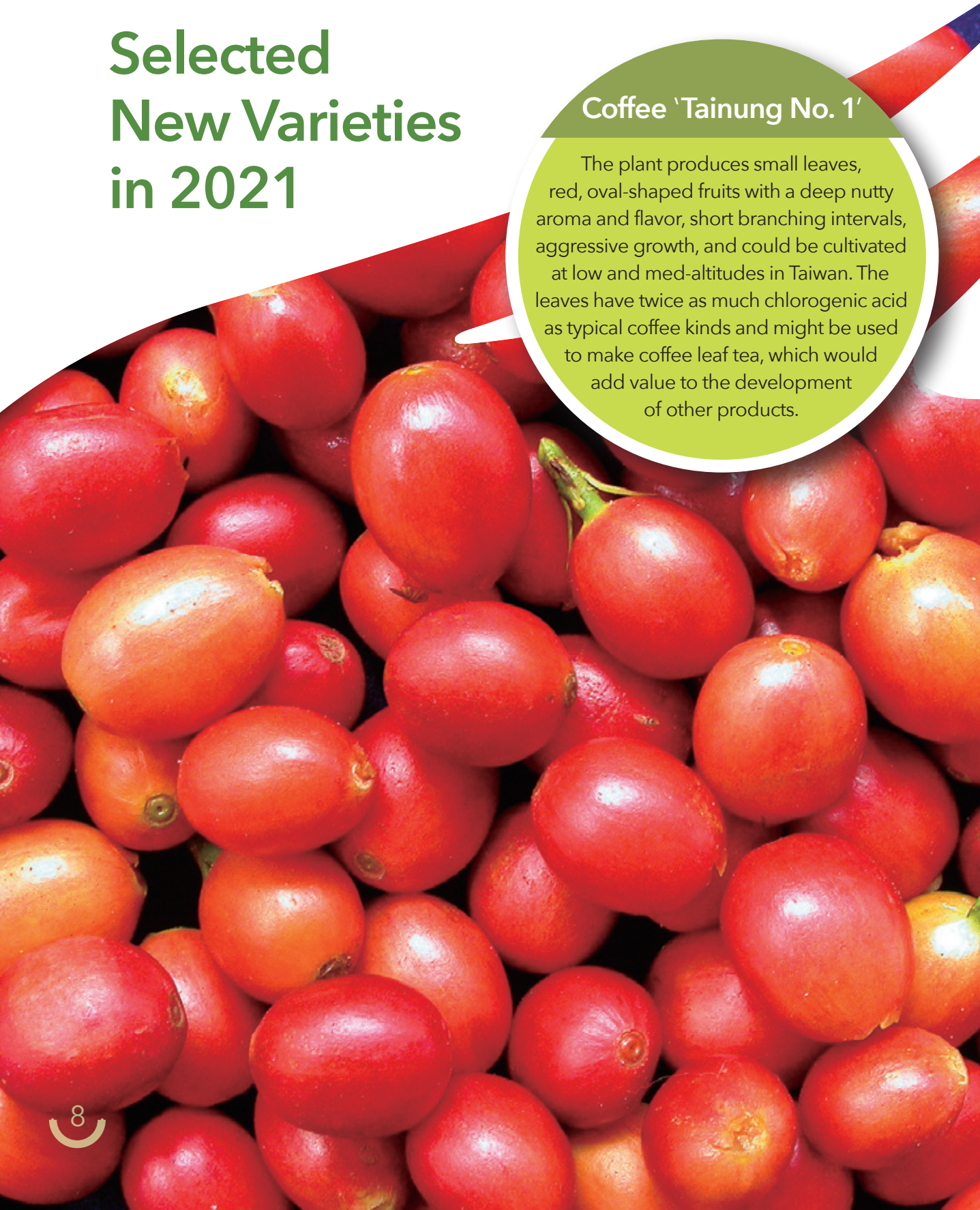
1. Development of communication tools: to incubate farmers for promoting new knowledge and improve the business ability of enterprises.

2. Innovation of service mode: to construct networks for product promotion and develop digital technology services.

3. Application of value-added science and technology: to increase the value of industrial innovation and create business prospects for industrial development.



Selected New Varieties in 2021



Coffee 'Tainung No. 1'

The plant produces small leaves, red, oval-shaped fruits with a deep nutty aroma and flavor, short branching intervals, aggressive growth, and could be cultivated at low and med-altitudes in Taiwan. The leaves have twice as much chlorogenic acid as typical coffee kinds and might be used to make coffee leaf tea, which would add value to the development of other products.







Strawberry 'Tainung No. 1'

Plant shape is large leaves, semi-upright type. The color of the conical fruit is dark red, and the flesh of the longitudinal section is red. After planting in early October every year in Taiwan, the flowering period and fruit maturity period to more than 50% start in mid-November and in early December, respectively. The average hardness of the fruits cultivated in facilities is 0.75-0.98 kg/cm^2, the sweetness range is 8.55-10.44 °Brix, and the acidity range is 0.27-0.36%, with mellow frankincense and fruit acid aroma. The fresh food flavor is very good, also suitable for baking cake decoration or making top jams and desserts.

Rice 'Tainung No. 85'

This variety contains a resistance gene found in Indian wild rice germplasm that can resistant to brown planthopper biotypes. The resistance gene was transferred into the aromatic rice variety 'Tainung No. 71' (Yihchuan aromatic rice) by hybridization and the application of molecular marker precision selection technology. The new variety, 'Tainung No. 85' can now resistant various biotypes of brown planthopper, with straight flag leaves, early maturity, good eating quality, and taro aroma traits.







Peanut 'Tainung No. 11'

The plant is suited for mechanized harvesting since it is upright and lodging resistant. The stem is green and has three to six branches, oval-shaped leaves, and yellow flowers. It often takes the characteristics of a two-seed pod, weak beaks, weak constrictions, pink seed coats, high oleic acid content (>75%), and stable oil characteristics that can extend shelf life from three months to as many as six months.



Peanut 'Tainung No. 11'





Potato 'Tainung No. 4'

The new variety is resistant to late blight disease with some characteristics such as high yield and large size of tubers, and the large size of tubers accounts for 70% of total yield. It has thin skin, shallow bud eyes, and good shape. It is suitable for stewing, with less gelatinization and strong flavor, and it is suitable for various cooking methods. The color of fried chip will not be brown while it is fried, because it contains 22% dry matter and less reducing sugar. The good features of crisp texture and strong potato flavor of chips make 'Tainung No. 4' perfect for processing.

Cauliflower 'Fengshan No. 2'

It's a F_1 hybrid of semi-loose curd and light-green stalk. A single curd weight about 430 g. It tastes tender and has the characteristics of early maturity and heat tolerance. It can grow and develop curd naturally in facilities with daytime temperature ranging 35-43°C and average temperature of least 32°C. No bracting or purple coloring occurrence on curd surface in summer.



Low-chill peaches

Since 1980, TARI has conducted evaluation and breeding for low-chill peaches with a chilling requirement under 200 CU (about 600-800 CU for temperate peaches), low acidity, sweet taste, and attractive look. TARI has released 10 varieties of low-chill peaches (100-180 CU) which can be produced in subtropical Taiwan and used as the crucial materials in other low-chill peach breeding programs.























R&D of New Technologies

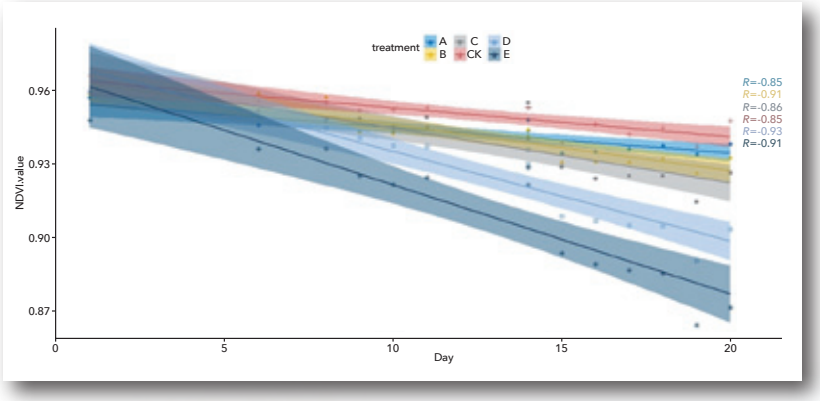
Smart Agricultural Technology R&D

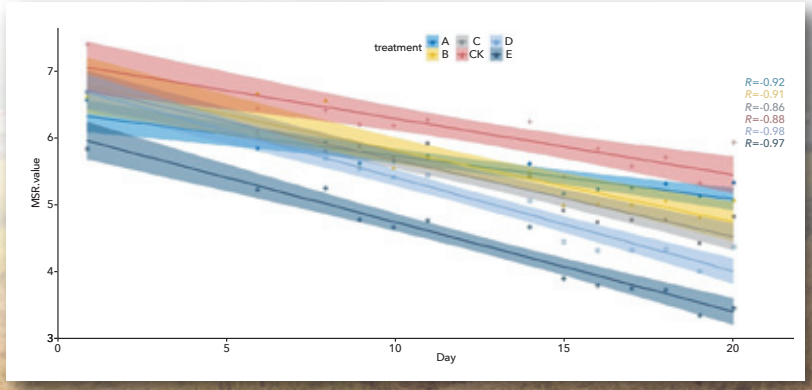


In Taiwan, rice industry encounters severe structural problems and the risk of climate change, particularly the rapid ageing and low fertility rate of the farmer population. TARI encouraged the research and development of intelligent agriculture technologies in ordering to save labor and improve farming technical efficiency. Rice cultivation has followed conventional ponding (CP) irrigation, which requested more water usage, for a long time in Taiwan paddy. We abide by conventional cultivation to irrigate, which we maintain the water level at 3-5 cm above the soil in whole growing period, and stop irrigating on the period of soil drying until maturity. Under the other management, alternative wet and dry management (AWD), we add water into field at 3-5 cm above the soil after 24 hours when field water level drops to 0, and repeat it until maturity. Importantly, we stop watering in field drying stage, and avoid water outage during heading stage. Moreever, various sensors are used to monitor the paddy environmental factors such as water level, relative humidity and electronic flow meters. According to the feedback of the paddy irrigation received from remote control system, rice farmers can track the paddy water level in real time and control irrigation through mobile phones. The test results indicate that compared with CP treatment, using intelligent sensors to conduct AWD treatment would effectively save 20%-30% water consumption and up to 75% working time based on the same yield potential.



One of the most significant food crops in Asia is rice. The rice planted land is more than 160,000 hectares in Taiwan, however brown planthopper damage to the second crop rice is a frequent occurrence. It is crucial to monitor insects efficiently and comfortably while dealing with a constant personnel deficit. TARI has made an effort to collect spectral images and evaluate the vegetation indices, Normalized Difference Vegetation Index (NDVI), Modified Simple Ratio (MSR), and Simple Ratio Red (SRRED), using a drone equipped with a multispectral Micasense Rededge-M camera. The NDVI, MSR, and SRRED regression curves, with coefficient R^2 values of 0.79, satisfied the regression models' conditions for normality, independence, homogeneity of variance, and significance. It can assist in judgments regarding the timing of preventative measures and be used to determine whether the number of brown planthoppers in the rice plants has reached harmful levels.





Treatment	Planthoppers per hill
A	60
B	125
C	250
D	500
E	1,000
CK	0

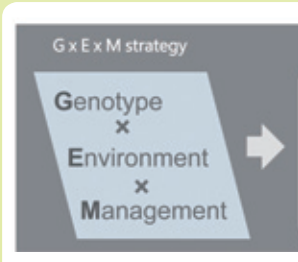
Fruit and vegetable harvesting is a labor-intensive task that needs a lot of laborers. TARI carries out a research and development on the unmanned and intelligently guided vehicle of loading and transportation the vegetables and fruits low-temperature precooling container in the facility, which devices including automatic fruit and vegetable container picking, carrying, transportation, and positioning systems, automatic rack loading a system, and so forth. To maintain the high quality of agricultural goods and minimize fruit and vegetable loss, the utility model can be used to keep the products under low-temperature storage after harvest during the transportation.



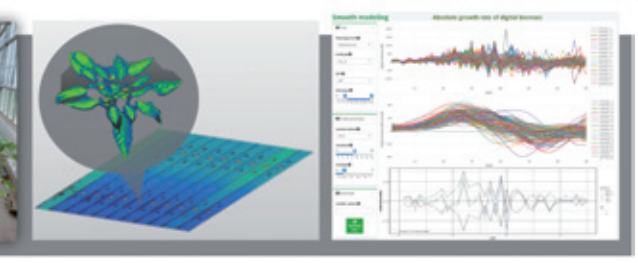
Development of Core Collections of Genome Resources and Establishment of a Fast-Precision Breeding Platform

In order to lower the cost of germplasm preservation and increase use efficiency, TARI has built the core collections of major crops, such as tomato and vegetable soybean, utilizing genome-wide genotyping or phenotyping. After eliminating duplications, two core collections of 292 lines of tomato and 226 lines of soybean were established, which accounts for 90% genetic diversity. The next generation of genomics and phenomics analytic technologies were introduced to establish the phenomics databases (more than 20,000 phenotyping records) and the genomics databases (more than 6,795 genome-wide genotyping records) for the core collections of tomato and vegetable soybean. These databases were further integrated into a crop-specific fast-precise breeding platform. However, crop traits are usually affected by the external environment. In addition, traditional breeding still relies on the phenotype investigation of crops. Therefore, the international research community has developed various high-throughput and non-invasive phenomics





platforms for efficient plant phenotyping. TARI also has already planned the National Plant Phenomic Center, which is expected to be established in 2023. The center contains the phenomics facilities that can convert the acquired images into crop traits and be powerful tools for botany, plant physiology, exploration of functional genes, germplasm screening, breeding selection, crop modeling, and the interactions of plant-pathogen by equipping with micro weather stations and environmental control greenhouses. Finally, the center can be the basis for developing a fast-precision breeding platform.

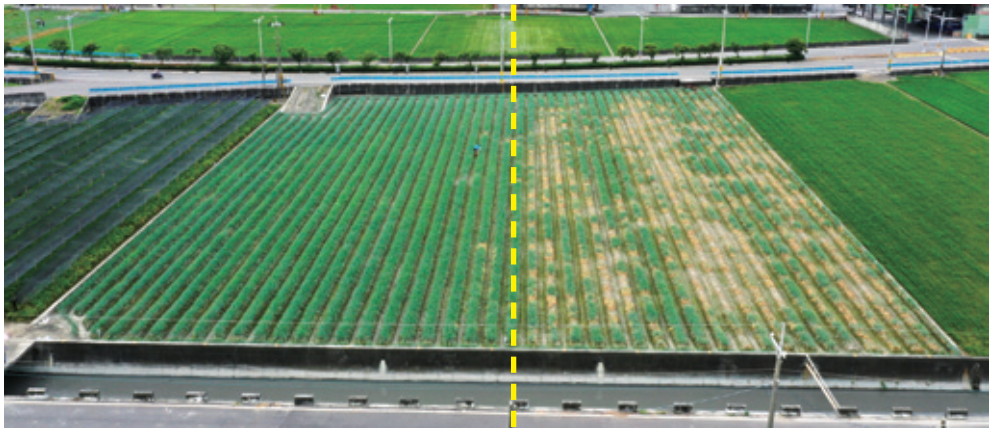






Integrated Pest Management Techniques for Green Onion

Taiwan has experienced an increase in the frequency of heavy rainfall, droughts, and floods in recent years, making green onion plants more prone to stem rot, leaf blight, and even widespread death. At first, people thought that the heavy rain and flooding led to poor growth, but according to TARI's research, most of these losses were caused by a kind of microorganism, *Phytophthora nicotianae* Breda de Haan. Based on the artificial environment simulation test, we preliminarily concluded that the conditions, under which the disease of Taiwan's green onion is prone to occur in summer and autumn, are overcast and rainy for more than two consecutive days. Because the disease cannot be eradicated by chemical pesticides alone, integrated pest management could be applied to control the disease, including no-*Phytophthora* contaminated green onion suckers, rational fertilization, weekly-spraying neutralized phosphite acid solution once every 2 weeks about 2 months before heavy rainfall, as well as fungicide-spraying 7days or less and 1 day before the heavy rainfall.



These crop health management measures could significantly reduce the occurrence of disease and yield loss. During a continuous drought period, the green onion is prone to insects, particularly beet armyworm, *Spodoptera exigua*. Green onion fields in the same region can hang beet armyworm pheromone traps together to trap and kill male moths and monitor the number of armyworms. When the number of insects exceeds the warning limit, the number and pesticide resistance of beet armyworm can be reduced by the timely application of *Bacillus turingiensis* and the rotation of different classes of pesticides. Furthermore, the institute found that the treatment of green onion seedlings with *Bacillus amyloliquefaciens* T33SR2 can greatly reduce the root nodulation caused by root-knot nematodes during the cultivation process. If green onion plants are regularly sprinkled with relatively safe and low-risk hypochlorous acid solution, the damage caused by bacterial soft rot can also be reduced.





New Services

Development and Application of Crop Growth Models on Yield Forecasting



The main purpose of crop growth analysis is to accurately evaluate and simulate the crop yield to effectively improve the cultivation and management technology and enhance its productivity. The crop growth model has the potential to quantitatively analyze environmental changes in crop growth and development to assist field management. Taking the Green Gold industry, with the green soybean of Taiwan exported to Japan as an example, the GLYCIM soybean growth model was regularly used as a tool to update the growth period and yield simulation results with weather forecasts and convert them into information that is easy to read for the whole industry. The research variety is Kaohsiung 9. Using the field observation data accumulated over many years, an empirical formula for estimating the crop parameters and fresh pod weight of the variety was established, and the accuracy of the model was verified. After sowing, meteorological observations, forecasts, and historical data of the current year are used for simulation. The forecast data used are the global cluster model forecast products produced by the Central Weather Bureau. The expected date of flowering, pod setting, pod filling, and soybean harvest, as well as the possible yield forecast results, are then proposed. The simulation results are updated once a week to provide the industry with an understanding of the impact of environmental changes on important production dates and expected yields. Comparing the field observation results, the error between the simulated flowering date and the actual value is within two days, and



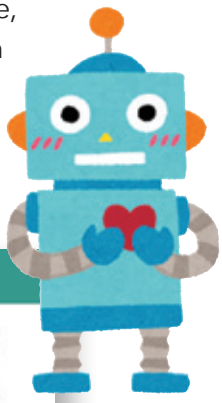
the simulated harvest date is close to the actual last harvest date in the field. The accuracy of the model has been verified by the continuous collection of simulated and measured yield data.

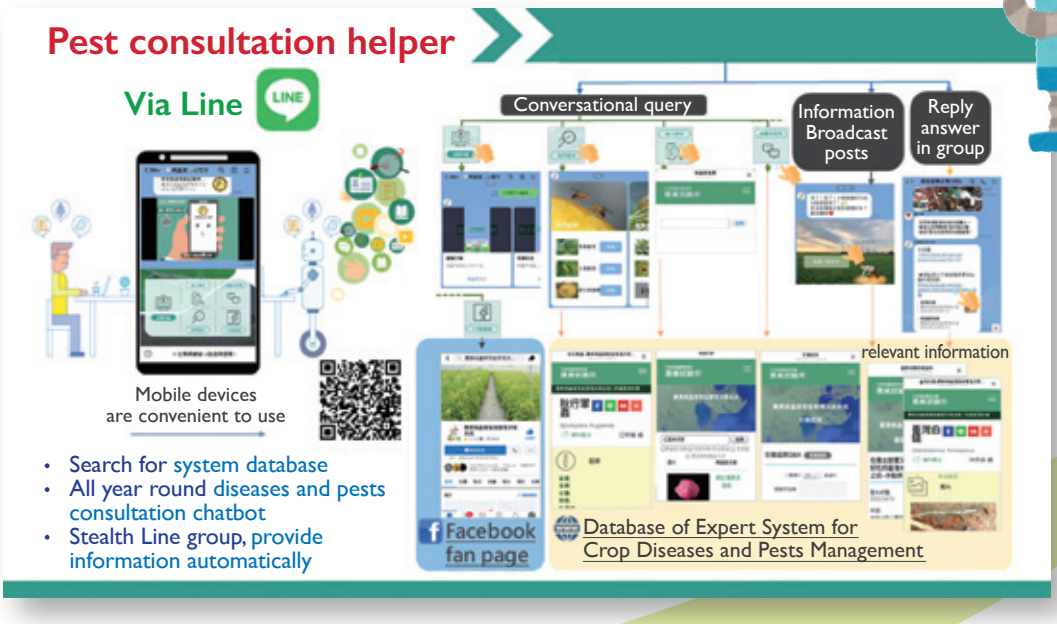
The yield forecasting can also achieved by image analysis and machine learning. We can calculate the leaf area of the cucumber plant and further estimate the leaf area index by using the self-developed facility crop leaf area real-time monitoring and environmental sensing system, along with Python language to write leaf area analysis and calculation software, as well as Ndimage, Polyfit, Scipy, Polyval, and other packages to perform image output, linear fitting, calculation, and regression equation output. Then, the yield prediction is carried out in a regression model using random forest machine learning. To achieve more accurate predictions the inputs of established model includes environmental parameters related to yield and leaf area. The accuracy of model was evaluated with different indicators (RMSE, MAE). The established model

has been appropriately applied to the yield prediction of cucumber, following a week (7 days later). With the increased amount of information collected, we look forward to improving the accuracy of yield prediction and number of predictable days in the future to provide better reference data for growers. This will enable growers to further master product supply capacity and status, formulate appropriate management models and effective strategies, and visually display the forecast data of the next week's yield through the website loading the model of Flask platform architecture so that growers can quickly grasp trend changes and then make relevant decisions.

Crop Diseases and Pests Chatbot Service

Farmers require years of experience to determine the cause of crop damage accurately, to assist farmers in the process of crop cultivation, TARI developed a chatbot service, which is "Pest consultation helper" via Line. This chatbot is linked to the "Expert System for Crop Diseases and Pests Management", which integrate information on various crop diseases and pests, and use easy-to-understand content to search for crops diseases and pests, can obtain relevant prevention and control information quickly. Also combined with Facebook and the system webpage, using the chatbot module, it can answer relevant information in real time, as if always accompanied by a disease and pest expert.





Theme

The Basis of TARI's Corn Research and the Breeder- Dr. Guang-Jauh Shieh

Since the 1980s, TARI has conducted research on maize breeding. So far, TARI has bred nine corn varieties, including six feed corn and three table use corn varieties. The main breeder, Dr. Guang-Jauh Shieh, joined TARI in 1984. He received his degree from the Department of Agronomy at National Chung Hsing University and began his career there after being assigned to the Dryland and Special Crop Laboratory, Crop Science Division. Since then, he has forged an indissoluble bond with corn.



1984 Tainung No. 351



1988 Tainung No. 1



1994 Tainung No. 2



1997 Tainung No. 3



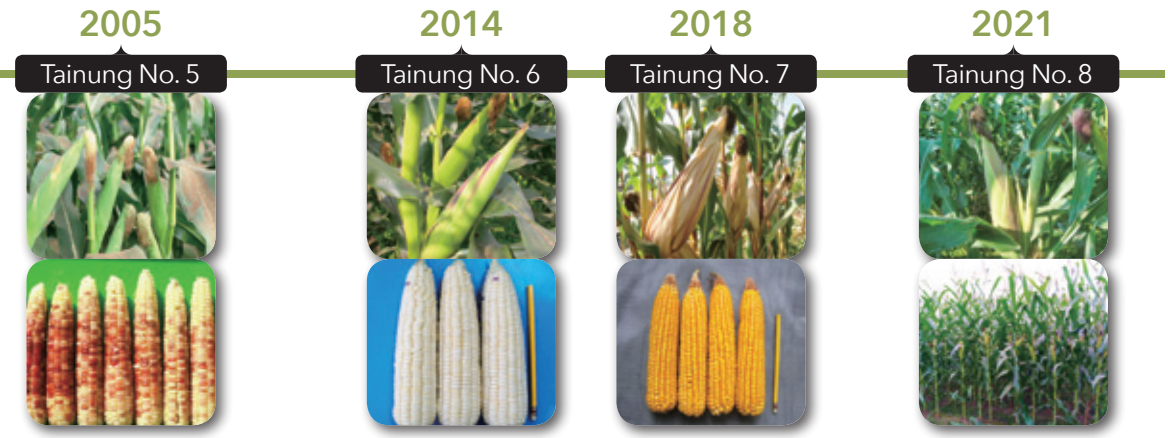
2002 Tainung No. 4



At first, in line with government policy and in response to the crop rotation and the fodder problem of livestock in Taiwan, Dr. Shieh studied on the breeding of feed and forage maize and developed Tainung No. 1-3 varieties. Later, during his doctoral course, he studied the character variation of Tainan-White Corn populations, an important local table use corn variety in Taiwan, as a source of breeding information. In 2002, white corn 'Tainung No. 4', the table use white corn suitable for boiling and grilling, was bred by crossing the inbred lines selected from Tainan white through self-crossing separation. At the same time, Dr. Shieh extended his research to the waxy corn popular in the market at that time, and in 2005, 'Tainung No. 5', commonly known as rainbow corn, was bred, which is still widely loved by consumers today. In 2014, white waxy corn 'Tainung No. 6' was bred, and the variety right was obtained.

Due to the requirement for the policy to restart the breeding of feed and forage maize, Dr. Shieh improved the variety of 'Tainung No. 1', which was less resistant to rust and bred 'Tainung No. 7', the feed maize with medium early maturity, high yield, and rust resistance in 2018. In 2021, 'Tainung No. 8', the forage maize with medium maturity, high forage grasses yield, dry matter rate, high nutrient digestibility, and rust resistance, was developed.

One of the most significant food and feed crops in the world is maize. Dr. Shieh retired in June 2022, he was still concerned about corn breeding and proposed possible future directions, including the development of the baby corn varieties for vegetables, the breeding of high-quality proteins, functional components, and stress-tolerant varieties, in the hopes that the young generation will carry forward his former achievements.



Achievements of International and Academic Cooperation

TARI participates in a diverse range of international collaborations. Through bilateral meetings, cooperation agreements, or other ways, we engage in continuing technical training with foreign officials and non-governmental organizations and participate in enduring partnerships with foreign research institutions. Due to the epidemic, TARI supported the Food and Fertilizer Technology Center (FFTC) to organize four online seminars. TARI participated in the "4 per 1000 Initiative" Day via video on November 10, 2021, which TARI's Director General Lin delivered a remarks via video outlining Taiwan's ongoing and upcoming carbon reduction and carbon sink approaches. These approaches will help Taiwan participate in the solution of global carbon reduction and carbon sink issues and integrate with related global research trends.











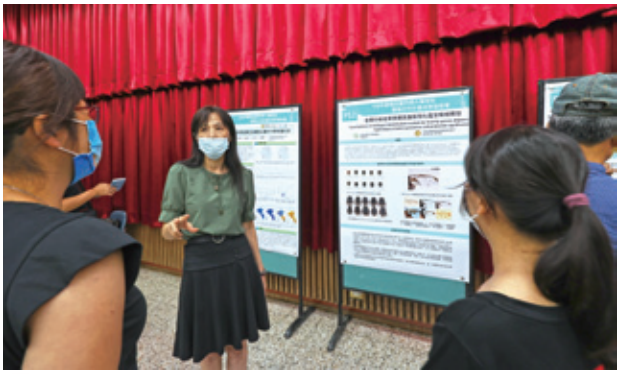




In addition, we collaborated with the International Cooperation and Development Fund (ICDF) to finish the research program on the dispersal and spread of weedy rice in Central America, completely appreciate the sources of Nicaragua weedy rice, the trade route causing spreading, and other facts, and provide efficient control strategies. On August 25, 2021, TARI held a video conference to release the findings. Staff from the ICDF, the Nicaraguan Rice Association (ANAR), the Instituto Nicaragüense de Tecnología Agropecuaria (INTA), the Department of Agronomy faculty and students from the National Agrarian University (UNA), and representatives of farmers who had access to the GIT Program's core technology were among those present. About 100 people participated in the warm dialogue and interaction.

TARI also collaborates academically with domestic universities including National Taiwan University, National Chung Hsing University, and National Yang Ming Chiao Tung University. The following are just a few examples of the agricultural concerns or future-focused issues that researchers from both sides jointly R&D: in-depth research on rice variety selection technology based on multispectral images; the intelligent identification module for the inspection and prevention of important fruit flies and pests and the evaluation on the application of controlled atmosphere technology in long-term storage and transportation of cut Oncidium flowers.



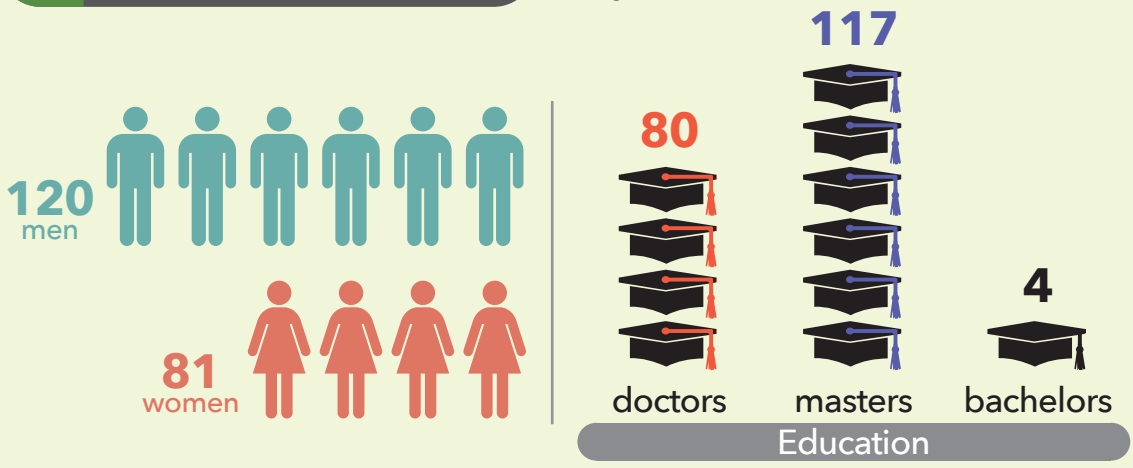




Resource
Introduction of TARI

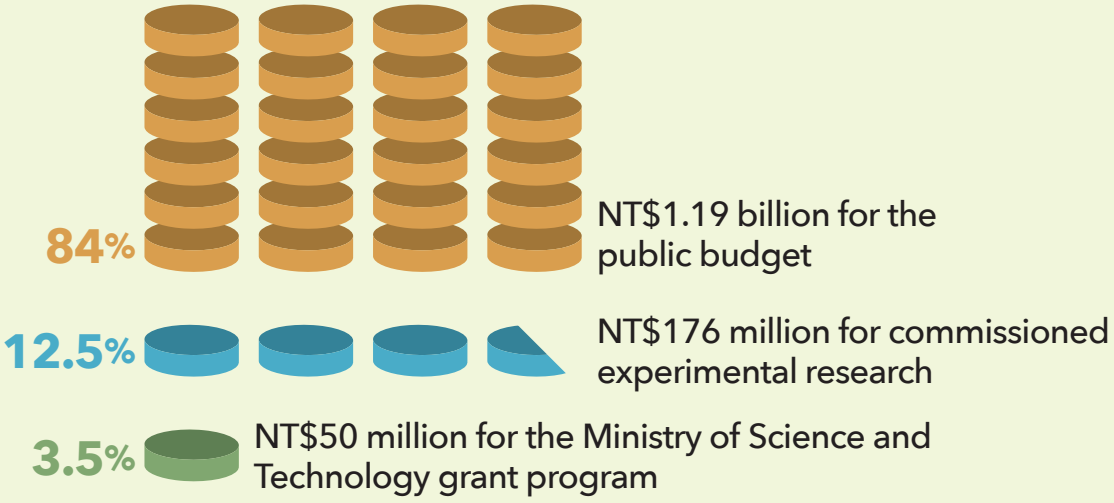
Manpower resource

TARI had 201 R&D personnel in 2021

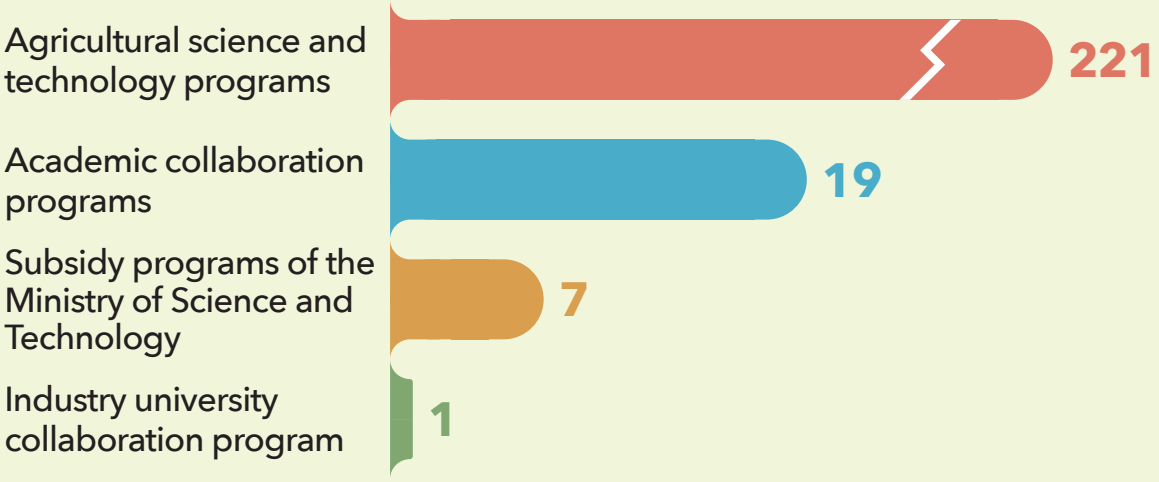


$ Expenditure

The total amount for 2021 was NT$1.42 billion



Number of projects



Cultivation center performance



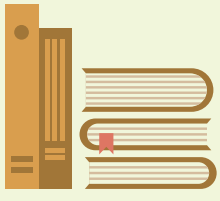
5 Newly signed enterprises

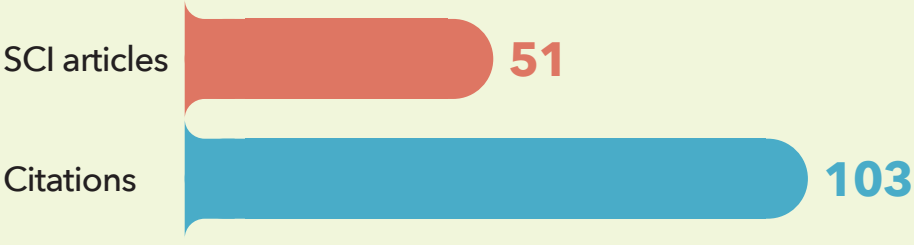
10 Mentoring enterprises

Facilitated **4** companies to invest over $160 million in additional capital

Increased employment to 25 people in **7** enterprises

Academic publications






TARI
1895


TARI