



REPUBLIC OF CYPRUS

AGRICULTURAL RESEARCH INSTITUTE
Centre of Excellence
in Agriculture and Environment

REVIEW FOR 2018-2019



MINISTRY OF AGRICULTURE,
RURAL DEVELOPMENT AND THE ENVIRONMENT
LEFKOSIA

DECEMBER 2020



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THE AGRICULTURAL RESEARCH INSTITUTE

The Agricultural Research Institute (ARI) was established in 1962 as a cooperative project between the Government of Cyprus and the United Nations Development Programme Fund, with the Food and Agriculture Organization (FAO) of the United Nations acting as the executive agency. It was entrusted to the Government of Cyprus in 1967 and had been firmly established as a research institution staffed predominantly by local scientists. ARI constitutes a Department of the Ministry of Agriculture, Rural Development and the Environment and is headquartered at Athalassa, on the outskirts of Lefkosia.

The Institute undertakes research within the wider domain of plant and animal production. Its mission is to provide high-quality scientific research with the objective of achieving a secure supply of safe, good quality food produced by methods financially, environmentally and socially sustainable. It develops or adapts and evaluates under local conditions scientific findings and technology available from international and regional research institutions. ARI's contribution to the solution of actual problems and to the introduction of new technological methods and approaches in agricultural production is highly valued, both locally and abroad, as reflected preeminently in its selection by the European Commission in 2000 as a Center of Excellence in Agriculture and Environment.

The ARI is organised in two divisions and eight sections: a) the Production Division which comprises the Sections of Plant Improvement, Fruit Trees, Vegetable Crops and Animal Production, and b) the Scientific Support Division, which comprises the Sections of Plant Protection, Natural Resources and Environment, Rural Development and Agrobiotechnology. The latter Division also includes the Variety Examination Center. The Institute is further equipped with state-of-the-art laboratories, a gene bank, an herbarium and a library carrying leading international agricultural journals and over 5,000 volumes.

Human resources at ARI consist of 31 scientists, specialised in various disciplines of plant and animal production, 31 technicians, 6 administrative and accounting employees, as well as 61 permanent labourers. Most of the scientists are PhD or MSc holders and all technicians have been trained either locally or abroad in their respective fields of work.

ARI's work is outlined in the Institute's Biennial Review. Research work of international interest is regularly published in international scientific journals. Transfer of research results and of new technology to the farming community is implemented through radio and television programmes, popular articles in local agricultural magazines and the daily press and through the extension of services of the Department of Agriculture. Innovative knowledge is also transferred through regular seminars, training sessions, demonstration trials and field days.

The Institute is the national AGRIS Center collecting, cataloguing and indexing the agricultural literature published in Cyprus and it is also the national CARIS Center collating information on ongoing research. All this information is supplied to FAO for inclusion in the global databases of the AGRIS and CARIS systems.

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DIRECTOR'S REPORT "In Search of Excellence"

Under the specter of the national and international economic crisis, the fundamental role of research and development in spearheading the economy has been widely acknowledged. In this current context, the Agricultural Research Institute (ARI) has reaffirmed its role as a driver of innovation and economic growth for the agricultural sector of Cyprus. Since its establishment, the Institute has been actively cooperating with national, regional and international organisations and research networks, including the Food and Agriculture Organization of the United Nations, the International Atomic Energy Agency, the International Centre for Agricultural Research in Dry Areas (ICARDA), the International Potato Centre, the International Centre for Advanced Agronomic Mediterranean Studies (CIHEAM) and numerous academic institutions. Supported by its wide network of cooperation, the ARI has augmented its efforts for providing solutions to problems arising from the management of agricultural systems and of their footprint on the environment, and for providing novel methods and tools for the optimisation of agricultural productivity and sustainability. These efforts have been pursued through a substantial number of research activities, outlined below, many of which are supported by the European Union (EU) and the Research and Innovation Foundation.

Plant Improvement has focused on the introduction, development and distribution of new varieties carrying the genetic potential for higher production, improved quality characteristics, resistance to pests and diseases and tolerance to abiotic stress, including drought. Particular emphasis has been given to the improvement of cereals, food legumes and fodders, utilising both field methods and molecular-genetic approaches. New varieties from the ARI's breeding programmes have been registered in the National Catalogue, including varieties of bread wheat, common vetch, ground nut and barley.

Plant Protection methods for the viral-disease-free production of citrus, grapevine and stone fruit stocks have been developed, including clonal and sanitary selection, thermotherapy, tissue culture and virus indexing techniques. The control of insect pests and soil-borne diseases has also been studied using conventional and advanced integrated methods in vegetables, grapevines, citrus and other fruit crops. Within the context of Integrated Crop Management (ICM), sustainable approaches for the control of pests and diseases in agricultural production have been tested, aimed at the production of agricultural commodities with minimal application of pesticides and other chemicals.

Horticultural research programmes have focused on improving vegetable cultural practices and at evaluating new scion and rootstock varieties. Research activity aimed at improving vegetable crop management practices and at preserving postharvest quality through optimised handling methods. Particular attention has been given to rootstock-scion interaction in grafted watermelon and melon with respect to crop performance, fruit quality and storability. Nutritional safety characteristics of salad crops have been evaluated in relation to the impact of nitrogen fertilisation strategies. Postharvest work further examined the ripening physiology, quality and storability of watermelon, melon and cactus pear, while emphasis has been laid on fruit physicochemical characterisation of local pomegranate clones established in an *ex situ* clonal collection. Work on viticulture included the evaluation of new table grape varieties on American rootstocks. Local wine grape varieties have been evaluated and their ampelographic description has been in progress along with the collection, evaluation and morphological characterisation of *in situ* populations of wild vines and of old neglected varieties. Local clones of pomegranate and several cherry varieties have been evaluated, and in citrus research work on rootstock evaluation continued. The conservation, evaluation and management of local olive genetic resources remain a key priority, while clonal characterisation of olive fruit ripening and its implications on oil attributes

has been pursued. Genebank and herbarium activities focused on the collection, *ex situ* conservation, characterisation, evaluation and utilisation of plant genetic resources, including native plants of the flora of Cyprus and local landraces.

Research activity in Agrobiotechnology encompassed molecular biology, food science, agricultural microbiology and agricultural chemistry projects. The antioxidant and antimicrobial properties of natural products such as essential oils and plant extracts have been investigated. The impact of treated waste water use on the microbial load of fruits and vegetables has been explored. Bacteria able to degrade fungicides and herbicides have been isolated and characterised, and the same approach was used for the remediation of other recalcitrant pollutants such as petroleum hydrocarbons. Screening of local isolated microalgae strains was performed in order to isolate efficient and promising strains for biofuel production and added-value co-products.

Research activities in Soil Science related to the design and application of closed hydroponic systems adapted to Cyprus conditions. Emphasis has also been given to the utilisation of endemic plants for floricultural purposes. Increasing water use efficiency, preventing pollution and using environmentally friendly local substrates have been among the main objectives. The potential for using biomass for biofuel and energy production in Cyprus and the use of agricultural waste products and by-products have been examined.

In Animal Production research aimed at enhancing productivity through improved breeding methods, management techniques and feeding practices. The effects of artificial rearing practices on lamb and kid growth and on dam milk performance have been investigated. The genetic improvement of economically important characters, such as milk, meat, and fecundity, has been pursued by methods of selection. A project for combating the scrapie disease in sheep, using molecular-genetic methods, has been successfully implemented. The Chios sheep unit of ARI at Athalassa has been transformed into a nucleus herd of about 500 disease-resistant animals, which provides farmers with scrapie-resistant stock of high genetic value. Additional studies have been initiated to combat the scrapie disease in goats, by characterising further the various scrapie genotypes in the ARI Damascus goat unit.

Agro-economic studies have been at the core of activity related to Rural Development, as time-series data and market prices were utilised for the prediction of market trends for crop and animal products. Targeted studies, commissioned by the Ministry of Agriculture, Rural Development and the Environment, have been conducted on agricultural economics and the trade of agricultural products. Work on robotic technology in agriculture has also been conducted and the newly established Remote Sensing Laboratory (RSL) continued its work on remote sensing and geo-information for agricultural and environmental applications.

The contribution of the ARI to agriculture and the environment has been valuable and substantial; it has contributed through concerted actions to the improvement of agricultural production in Cyprus, by generating solutions to emerging problems and by introducing innovative technology, thus promoting a better future for the Cypriot farmer. Furthermore, the ARI has functioned as a pivotal center for collection, evaluation and dissemination of information on agricultural matters and technology, and has incorporated in its scope of activities the training of scientists, agricultural extension officers, technicians and farmers. The selection of the ARI by the European Commission in 2000 as a Center of Excellence in Agriculture and Environment has constituted a landmark recognition reflecting on the high standard of scientific research conducted, and on its contribution to agricultural development and the protection of the environment. It is a pleasure for me to acknowledge both the tireless efforts of the ARI staff and their commitment to quality research, which remains the foundation for all future achievements.



Dr Dora S. Chimonidou
Director

PLANT IMPROVEMENT

The main activities of the Plant Improvement Section concern the improvement through breeding of barley, forage plants, seed and food legumes, durum and bread wheat, triticale, as well as studies of genetic and environmental factors affecting their productivity, quality and resistance to diseases. Work also aims at improving cultural practices of forage plants, grain cereals, legumes and aromatic plants.

Barley is the cereal most adapted to the often harsh agroclimatic conditions of Cyprus. Spring barley is grown in Cyprus during winter as the main rain-fed crop for livestock feed as hay or grain. The barley breeding programme aims at the development of new, well-adapted and drought-tolerant cultivars with improved quality characteristics, and of naked barley cultivars for human consumption and as feed for monogastric animals. Wild species (*Hordeum vulgare* spp. *agriocrithon Aberg*) and landraces are used in crosses to improve biotic and abiotic stress resistance.

The durum wheat improvement programme aims to enhance the productivity and economic value of grain and straw through hybridisation and selection for agronomic performance and quality. Environmental and genetic factors affecting grain yield, water use efficiency and quality of durum wheat are examined and new genetic lines of increased drought tolerance under field conditions have been identified. Cultural practices are also examined for improved production. The cereal technology programme, which is complementary to the improvement programme, aims at identifying varieties of superior quality. Factors that could enhance the quality of industrially made local bread are also evaluated in collaboration with local mills and bakers.

Forage production has increased both quantitatively and qualitatively through the introduction of new species/varieties, selection of local material and improved management practices. Crops under investigation include barley, oats, bread wheat, vetch, alfalfa, triticale and peas. Triticale is a fast-developing crop introduced mainly by cattle growers in the last few years. Two new varieties, originated from the Triticale improvement programme, were sent for testing and are now under registration procedures to the National Catalogue.

The genetic improvement of Cyprus cowpea landraces with respect to climate change is a long-term programme aiming at the enhancement of adaptation of this important crop using innovative field phenotyping methods. The project has further successfully isolated symbiotic nitrogen-fixing bacteria from local populations. In addition, work on the on-farm (*in situ*) conservation of Cyprus eggplant landraces through a novel approach has progressed very satisfactorily.

Research on aromatic and medicinal plants focuses on cultural techniques required for the main aromatic and medicinal plants grown in Cyprus. New species of medicinal and aromatic plants, such as stevia (*Stevia rebaudiana* Bertoni), with multiple prospective benefits to consumer health, are studied as alternative crops for Cypriot farmers.

CROP IMPROVEMENT

Breeding barley for grain and hay under conventional and organic agriculture

A major aim of the barley breeding programme, both for conventional and organic agriculture, is the creation of varieties that are density-neutral or density-independent, in order to make efficient use of the limited resources in Cyprus environments. Other specific aims include the development of cultivars with improved adaptation to climate change, improved drought and heat resistance and improved quality traits, such as threshability, hectolitre weight, grain uniformity and protein content. The development of cultivars suitable for dual grain and hay consumption, with improved stability of performance and reduced interaction with the environment has been a priority. An additional priority is the development of varieties appropriate for Organic Agriculture with increased tillering capacity and other specific traits using an innovative field selection methodology based on the unique properties of the Honeycomb Selection Designs and the prognostic breeding paradigm. Trials are performed in five different locations across the island, employing a series of crosses between locally adapted material and promising imported germplasm. Additional trials explore internationally available germplasm, in collaboration with CIMMYT and ICARDA. Following the global trend for a healthy and well-balanced human diet, the barley breeding programme has also focused on the development of naked barley



cultivars appropriate for human nutrition and on cultivars adaptable to organic cultivation. A new 2-row barley variety 'Politiko' has been registered in the National Catalogue. A new six-row barley cultivar, named Myrtou, with improved biomass and tillering capacity has been subjected to the official national tests and is at the final stages of the registration process to the National Catalogue, while a new naked barley cultivar has entered the national trials. Innovative field phenotyping approaches are being developed. An important component of the barley and cowpea breeding programmes is bridging the gap between genotype and phenotype, employing novel methods of precision phenotyping at the single plant level grown under the Honeycomb Selection Designs and distances that eliminate the masking effects of interplant competition and soil heterogeneity. In this respect, a novel barley mutant, identified through our specific trials, was found associated with improved performance and is being further characterised. **(D.A. Fasoula)**

The new six-row barley cultivar Myrtou

National Management Committee Member for the COST Action FA1306: "The quest for tolerant varieties: phenotyping at plant and cellular level"

This Action recognises plant phenotyping as an emerging science and a major bottleneck to characterise germplasm and create climate change-resilient varieties. Although the Action concluded in 2018, the scientific network developed continues its activities, pursuing additional research and funding opportunities. **(D.A. Fasoula)**

National Management Committee Member for the COST Action CA16212 INDEPTH: "Impact of Nuclear Domains On Gene Expression and Plant Traits"

Plants have developed the ability to rapidly adapt their genome expression in response to environmental challenges. This Action explores the epigenetic modifications in plant performance and adaptation mechanisms

towards mitigating the effects of climate change. ARI actively participates with its innovative field breeding methodology, using the Honeycomb Field Selection Designs and the Prognostic Breeding Paradigm. **(D.A. Fasoula)**

DIVERSIFOOD H2020 Research Project

This Horizon 2020 Project deals with a variety of crops, from maize and ancient cereals to legumes, and focuses, among others, on novel Participatory Breeding methods for conventional and organic agriculture, on the on-farm (*in situ*) conservation of traditional varieties and landraces and on the development of Community Seed Banks. It also deals with all relevant legislation, including matters under the International Treaty of Plant Genetic Resources for Food and Agriculture (Farmers' Rights and others).

(D.A. Fasoula, M. Omirou, I.M. Ioannides)



Aerial view of harvesting barley trials

Breeding durum wheat, bread wheat and triticale

The aim of the programme is to develop cultivars of high and stable grain yield under rain-fed conditions. Work is based mainly on two approaches: The first is the crossing of selected cultivars possessing desirable agronomic and quality characteristics, until a desired line is developed and checked in the field. A second and faster approach is the introduction of genetic material under development by CIMMYT and ICARDA, which is checked and selected under the climatic conditions of Cyprus. Sometimes a combination of these approaches is necessary. The practiced breeding method is a modification of the pedigree method, which retains for subsequent exploration F3 lines with a higher frequency of promising genes for high quality and agronomic characteristics positively associated with grain yield early in the programme. Outstanding F5 lines enter the preliminary yield trials, and the best of them proceed to Value for Cultivation and Use (VCU) tests for registration. The two durum wheat cultivars that are currently cultivated the most are the ARI varieties 'Ourania' and 'Hekabe'. Grown under organic farming conditions, these two varieties exhibited promising performance. New lines with improved quality characteristics are expected to replace these varieties. These new lines will exhibit better adaptability to climatic change and the harsh climatic conditions of Cyprus than the older durum varieties.

Forage production could be improved both quantitatively and qualitatively through crossing and selection. Thus, the programme aims at identifying new varieties with high forage production and high nutritional value. The most promising lines are tested at several sites, in order to assess dry yield potential, nutritional value, disease and lodging resistance. Bread wheat lines having tall, leafy and strong stem are listed in the National Catalogue under the names 'Akhelia' and 'Yiolou'. These varieties proved to be tolerant to dry conditions and yield much better than durum wheat. A new addition to the breeding programme has emerged from the needs of farmers of small ruminant animals, and these are the awnless bread wheat lines created in the last few years. These lines show a huge potential for animal feed since they produce high quality and quantity of forage under the tough Cyprus climatic conditions. They are already expected among the small ruminant growers after they were showcased in a field day in Akhelia experimental station with huge success. Finally, the most promising

triticale lines, in terms of quality and yield, from the ARI development programme were promoted for advanced trials and are now under registration in the National Catalogue. **(A. Pallides)**

Grain and forage legumes

In recent years, rainfed legumes have become increasingly popular, because of their efficient use in rotation systems with cereals and their higher feeding value than cereals, either as grain or as dry forage mass. Thus, in current research projects special emphasis has been placed on the evaluation of common vetch, field peas and alfalfa, among others, for forage production. One of the Plant Improvement Section's most crucial duties is the maintenance of breeder's seed for all the varieties produced at the ARI. This is also the case for legumes where the Section preserves the purity of many varieties of common vetch, field pea, fava beans, lentils, chickpea, bitter vetch, groundnut and other. **(A. Pallides)**. Two new groundnut varieties have been registered in the National Catalogue under the names of 'Ntopia' and 'Nikoklia'. These two varieties have been tested by the farmers and were highly evaluated by them for their potential in replacing the current American cultivar that is being produced in Cyprus. **(A. Pallides)**. Alfalfa (*Medicago sativa*) is a high-protein feeding stuff of great importance. Four populations have been stabilised and are currently evaluated for their yield and quality potential. One variety ('Ntopia') has been registered in the National Catalogue. **(D.A. Fasoula, A. Pallides)**

Cowpea

The cowpea is a subtropical legume with substantial tolerance to heat and the drier conditions experienced in Cyprus, and a favourite traditional food among the local population. The project aims at the development of



improved cowpea varieties, well-adapted to the changing climate conditions of south-east Mediterranean using novel field phenotyping methods for both the above ground and root components. The project also involves the study of the microbial environment of local cowpea landraces and the relevant plant-microbe interactions. Nitrogen-fixing symbiotic bacteria have been isolated from Cyprus cowpea landraces and are being studied at the molecular level. A participatory breeding component of the project is successfully executed, with the involvement of local farmers and extension officers across Cyprus. **(D.A. Fasoula)**

DIVERSIFOOD: View of the maize trials

AROMATIC AND MEDICINAL PLANTS

Stevia field trials

In 2018 the stevia experiment which was established at Tochni Experimental Station was continued. Two harvests took place and the results are presented in the following tables. **Table 1** shows the effect of the irrigation level on the height, the fresh weight of the plants, the dry weight of the leaves, the rebaudioside A, the stevioside and the total phenolic content during the first and second harvest. **Table 2** presents the results of t-test and Descriptive Statistics for plant height, fresh plant weight, dry leaves weight, rebaudioside A, stevioside and total phenolic content by fertilisation frequency. The results of t-test and Descriptive Statistics for plant height, fresh plant weight, dry leaves weight, rebaudioside A, stevioside and total phenolic content by cut height show that there are not significant statistical differences. Also, a demonstration field of 0.5 acre was established and one harvest took place that gave about 905 kilos of fresh plant.

In addition, the study, evaluation and exploitation of edible medicinal and aromatic plants of Cyprus flora have been launched in 2109. Four species will be studied: *Crithmum maritimum*, *Helichrysum italicum*, *Capparis spinosa* and *Cistus creticus*. The effect of irrigation and fertilisation on plant production will be examined. Furthermore, the project aims to assess the antioxidant and antimicrobial activity of plant extracts and the investigation of the inhibitory action of these extracts against the activity of xanthine oxidase.

Researchers of the Section also participate in the 3PRO-TROODOS project (INTEGRATED/0916_0061) funded by the Research and Innovation Foundation. In 2019 an ethno-botanical survey started on the use of medicinal and aromatic plants in Troodos area and seed collection of selected endemic medicinal and aromatic plants of Troodos. Selected plant species will be established at Saittas Experimental Station and tested by local farmers.

(C. Stavridou)

Table 1. Mean comparisons for plant height, fresh weight per plant, dry leaves weight per plant, and leaf sugar content, rebaudioside A, stevioside and total phenolic content at first and second harvest.

Irrigation level	Plant height		Fresh weight per plant		Dry leaves weight per plant		Rebaudioside A		Stevioside		Total Phenolic Content	
	(cm)	(cm)	(g)	(g)	(g)	(g)	(mg.g ⁻¹ dw)	(mg.g ⁻¹ dw)	(mg.g ⁻¹ dw)	(mg.g ⁻¹ dw)	(g GAE/100g)	(g GAE/100g)
	1 st harvest	2 nd harvest	1 st harvest	2 nd harvest	1 st harvest	2 nd harvest	1 st harvest	2 nd harvest	1 st harvest	2 nd harvest	1 st harvest	2 nd harvest
Sig.	*	ns	ns	ns	ns	ns	ns	*	*	ns	ns	ns
100% ET	76.98 b	60.73	447.61	273.63	73.86	40.13	49.87	37.61 a	65.29 b	59.23	7.6	6.51
80% ET	68.78 a	53.68	389.29	257.56	72.5	39.42	55.54	53.42 c	55.72 a	62.00	7.03	6.06
60% ET	68.80 a	54.68	402.98	188.75	72.37	29.69	54.09	45.60 b	59.06 ab	62.32	7.05	6.10

Means within columns followed by different letters denote significant ($P < 0.05$) differences according to Tukey HSD test.

Table 2. Results of t-test and Descriptive Statistics for plant height (cm), fresh plant weight (g), dry leaves weight (g), rebaudioside A (mg.g-1dw), stevioside (mg.g-1dw) and total phenolic content (g GAE/100G) by fertilisation frequency.

Variable	Fertilization frequency	M		SEM		t		df		p	
		1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd
		harvest	harvest	harvest	harvest	harvest	harvest	harvest	harvest	harvest	harvest
Plant height	2 doses	74.92	62.52	1.60	1.39	3.04	5.65	34	33	0.004	≥0.001
	3 doses	68.12	49.94	1.56	1.75						
Fresh plant weight	2 doses	484.91	314.22	15.46	19.49	4.72	5.63	27.62	33	≥0.001	≥0.001
	3 doses	341.68	164.38	26.11	17.99						
Dry leaves weight	2 doses	83.67	45.34	2.09	2.48	3.91	4.78	22.59	33	≥0.001	≥0.001
	3 doses	62.15	27.36	5.09	2.85						
Rebaudioside A	2 doses	56.31	44.97	2.40	1.96	1.59	-0.35	34	33	ns	ns
	3 doses	50.01	46.14	3.14	2.69						
Stevioside	2 doses	60.75	63.05	2.71	1.88	0.44	1.44	34	33	ns	ns
	3 doses	52.29	59.14	1.90	1.96						
Total phenolic content	2 doses	7.28	6.22	0.30	0.13	0.32	-0.04	34	33	ns	ns
	3 doses	7.17	6.23	0.16	0.20						

M: mean; SEM: standard error of the mean; df: degrees of freedom

FRUIT TREES

Research activity in the Fruit Trees Section encompasses methods of managing yield and quality of fruit trees and vines and optimising production cost. In viticulture, research work on evaluation of table grape and wine grape varieties and rootstocks, as well as ampelographic description and conservation of traditional grape varieties has continued. Local clones of pomegranate and several cherry varieties were evaluated. Current research activity in citriculture focuses on rootstock-scion relations on calcareous soils and the evaluation of citrus varieties as scions grafted onto different rootstocks with respect to productivity and quality. The conservation, management and evaluation of local olive genetic resources have remained a key priority. Evaluation of olive genetic resources entails the elaiotechnical characterisation of olive oil as well as the physicochemical characterisation of olive fruit and olive paste with respect to clonal ripening profiles.

VITICULTURE

Evaluation of table grape varieties

For the evaluation of new and traditional table grape varieties under different environmental conditions, two experimental plots were planted at the Saittas and Acheleia Experimental Stations. In Saittas, the newly introduced table grape varieties 'Red Globe', 'Superior', 'Fantasy Seedless', 'Crimson Seedless', 'Autumn Royal', 'Sublima' and the traditional varieties 'Veriko' and 'Sideritis' are under evaluation in terms of yield, quality and earliness. In Acheleia, in addition to the above, the varieties 'Prima', 'Black Emerald', 'Early Superior', 'Summer Muscat', 'Ora', 'Victoria', 'Italia', 'Calmeria' and 'Flame Seedless' were also introduced for evaluation. **(S. Savvides)**

Evaluation of table grape varieties grafted on American rootstocks

The imported table grape varieties 'Crimson Seedless', 'Autumn Royal', 'Fantasy Seedless', 'Black Emerald' and the autochthonous varieties 'Veriko' and 'Sideritis' grafted on the American rootstocks 110 Richter, 3309 Couderc, 41B, 99 Richter, 420A, 1103P and 140 Ruggeri were evaluated in terms of yield, fruit quality and earliness. The table grape varieties 'Fantasy Seedless', 'Black Emerald' and the autochthonous varieties 'Veriko' and 'Sideritis' were evaluated at the Acheleia Experimental Station and 'Autumn Royal' at the Saittas Experimental Station. 'Crimson Seedless' was evaluated at both locations. **(S. Savvides)**

Collection and conservation of table grape varieties



The aim of this project is to collect and preserve all the table grape varieties imported in Cyprus over the years. At the moment, a collection of 60 varieties has been established at the Acheleia Experimental Station. The collection of other table grape varieties continues. **(S. Savvides)**

Evaluation and tests for Distinctness, Uniformity and Stability (DUS) of traditional wine grape varieties

The traditional varieties 'Mavro', 'Xynisteri', 'Ofthalmo', 'Spourtiko', 'Maratheftiko', 'Morokanella', 'Malaga' and 'Lefkada' were evaluated in terms of yield and quality in comparison to the imported varieties 'Mataro', 'Cabernet Sauvignon', 'Merlot', 'Chardonnay' and 'Sauvignon Blanc'. The above varieties were also tested for distinctness, uniformity and stability in order to meet the Council Regulation 2100/94 on Community Plant Variety Rights. **(S. Savvides)**

Collection and ampelographic description of traditional table and wine grape varieties

The acquisition of primary and secondary descriptor data, according to the International Organisation of Wine and Vine (OIV) standards, of the traditional table grape varieties 'Veriko' and 'Sideritis' and the wine grape varieties 'Mavro', 'Xynisteri', 'Ofthalmo', 'Spourtiko', 'Maratheftiko', 'Morokanella', 'Omio', 'Promara', 'Skouro Mavro' and 'Kanella' and other autochthonous varieties has continued. (S. Savvides)

Evaluation of traditional wine grape varieties 'Maratheftiko' and 'Xynistry' grafted on American rootstocks

Evaluation of the traditional wine grape variety 'Maratheftiko' and 'Xynisteri', grafted on the American rootstocks 110 Richter, 3309 Couderc, 41B, 99 Richter, 420A and 140 Ruggeri, were performed at Kilani and Kannaviou respectively. Both varieties were evaluated in terms of yield, fruit quality and earliness. (S. Savvides)

Management and conservation of grapevine genetic resources



The long-term objective of this project is to preserve and study *in-situ* populations of wild vines as well as of old and neglected varieties and to promote their future utilisation. Wild vine plants have been recorded in six locations: Ayia, Stavros tis Psokas, Potamos tou Limniti, Potamos tou Pyrgou, Platys and Saramas. All plants are located along water streams and are found as climbers on the stems of pine and deciduous trees. Until now, more than 240 individual plants have been recorded. Work is still in progress for the *in situ* evaluation and morphological characterisation of all individual plants. An *ex-situ* collection has been established at Saittas Experimental Station with more than 130 wild vine accessions collected from the above locations (S. Savvides)

DECIDUOUS FRUIT TREES

Characterisation and evaluation of local pomegranate clones (*Punica granatum* L.)

Research regarding the evaluation of selected local pomegranate clones, planted at the Zygi Experimental Station, has been implemented as part of an interdisciplinary research programme under the coordination of the Postharvest Technology Laboratory. The purpose of this study is the characterisation and evaluation of local pomegranate clones concerning phenological, pomological-morphological and production characteristics. In particular, phenological development stages, growth and productivity of clones, morphological and qualitative characteristics of fruits, were examined in terms of yield and quality. (S. Ioannidou)

Evaluation of cherry varieties (*Prunus avium* L.)



Examination of nine cherry varieties (*Prunus avium* L.) has produced results in terms of production, fruit quality and maturation period. An experimental plantation of the varieties was established at Saittas Experimental Station. The varieties evaluated are: 'Bigarreau Burlat', 'Black Tartarian', 'Utah Giant', 'Bigarreau Ferbolous' (Verdel), 'Bigarreau Summit', 'Bigarreau Fercer' (Arcina), 'Bigarreau Reverchon' (Souche sandar), 'Bigarreau Lapins' and 'Van'. The aim of this work is to investigate the behaviour of Cherry varieties under the local agro-climatic conditions of Cyprus, in order to result with varieties that have excellent fruit quality. In addition, the evaluation of maturity time within the season was measured, in order to satisfy market needs for longer periods. (S. Ioannidou)

LIFE+ORGANIKO: Revamping organic farming and its products in the context of climate change mitigation strategies

The ultimate goal of the project was to demonstrate the comparative advantages of organic versus conventional farming and products using indicators of mitigation efficiency to climate change, agronomic and environmental quality, decreased children exposure to diet-based pesticides and healthy food promotion for better children's health. Experimental work was carried out for the needs of the LIFE+ORGANIKO programme under the coordination of the Agricultural Microbiology Laboratory. The impact of different agricultural practices on GHG emissions and fruit quality was examined under conventional and organic apple cultivation. **(S. Ioannidou)**



3PRO: Proactive Producer and Processor Networks for Troodos Mountains Agriculture

The project's general objective is to improve agricultural production and food processing in the Troodos Mountains of Cyprus, through social innovation, sustainable natural resource management and climate change adaptation. The Sector's contribution to the project will be aiming to sustainable fruit production with the application of protective nets in cherry and apple orchards. Sustainable fruit production improves natural and Agricultural Resource Management, leading to the conservation of economical, natural and cultural resources to the benefit of the society and the environment. Productivity, fruit quality and environmental impact of integrated fruit production under protective nets will be examined in the context of the project. **(S. Ioannidou)**

National catalogue varieties of fruit tree genera and species



In cooperation with the Department of Agriculture of Cyprus, the description of fruit plant varieties in order to be accepted for registration to the National Catalogue of Cyprus according to the provisions of the national legislation for the production and marketing of propagating material of fruit genera and species is conducted. **(S. Ioannidou)**

OLIVE CULTURE - OLIVE OIL TECHNOLOGY

Conservation, evaluation and management of olive genetic resources



Local olive genetic material is under conservation in the *ex situ* Collection of Olive Genetic Material (OCARICY) situated at the Tochni Experimental Station, in the context of the research project: "Management of the ARI *ex situ* Collection of Olive Genetic Material". The main objectives of the project are: a) proper *ex situ* conservation of the genetic resources; b) characterisation, identification and evaluation of genetic resources; c) implementation of actions for further prospection, collection and installation of local genetic material in the Collection; d) enrichment of OCARICY with genetic material from other countries.

(M.G. Emmanouilidou)

Characterisation and identification of indigenous olive germplasm from Cyprus using morphological and SSR markers

Implementation of the recently developed Cyprus National Register of Commercial Varieties mandates proper cataloguing of the material conserved in the *ex situ* Olive Collection at the Agricultural Research Institute of Cyprus. A total of 32 accessions were analysed using 11 morphological endocarp traits and 14 SSR markers. The SSR variability allowed segregation of 16 genotypes among accessions, which were clustered into three main groups based on genetic similarity. Similarity indexes among groups ranged from 0.63 to 0.65 and within groups were > 0.9. Lower morphological variability was detected among accessions, which conformed to three morphological profiles; moreover, the three morphological profiles corresponded to the three groups of genetic similarity obtained by SSR markers. The identification, based on the unique combination of SSR genotypes and endocarp morphologies, revealed the presence of three cultivars ('Kato Drys', 'Korakou' and 'Ladoelia') and 15 molecular variants that presented limited molecular differences but morphological profiles identical to their catalogued cultivars. Two cultivars, 'Ladoelia' and 'Kato Drys', demonstrated molecular variation. The current study underpins the efficient management of olive germplasm collections based on combined molecular and phenotypic characterisation of their accessions. The complete cataloguing of olive germplasm ensures the correct distribution of identified and authenticated material across national or international institutions. (M.G. Emmanouilidou, M.C. Kyriacou)

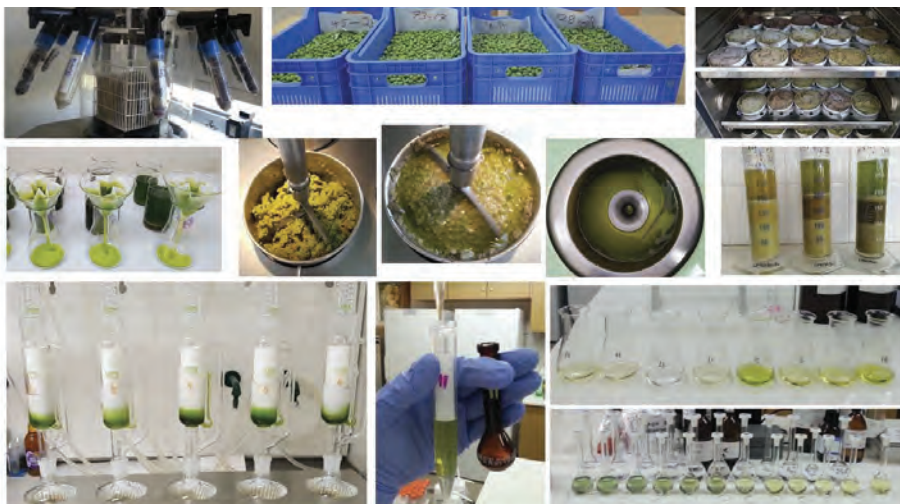
Elaeographic description of olive cultivars

Following the identification of local Cypriot olive genetic material, based on the unique combination of SSR genotypes and endocarp morphologies that revealed the presence of three local cultivars ('Kato Drys', 'Korakou' and 'Ladoelia'), a full elaiographic description for them was held. A total of 24 morphological characters of tree, leaf blade, fruit and stone described based on CPVO-TP/099/1 and UPOV-TG/99/4 Protocols for Distinctness, Uniformity and Stability Tests in Olive (*Olea europaea* L.). (M.G. Emmanouilidou)

True Healthy Olive Cultivars (THOC) Project

The Network of Olive Germplasm Banks of the International Olive Council (IOC), consisting of 3 international and 20 national banks has started the implementation of THOC project. The objectives of this project are the following: a) authenticate 101 most common in national level and most commonly exchanged among IOC network countries commercial cultivars; b) test the absence of the main pathogens that cause epidemics spread by plant interchange; c) establish reference collections of DNA and endocarps from the authenticated cultivars; d) create an online database of the morphological (UPOV) and SSR profiles of the authenticated and pathogen-free cultivars; e) provide members of IOC Network with true-to-type and pathogen-free genetic material to facilitate initial plants for potential olive plant certification programmes in the corresponding countries. **(M.G. Emmanouilidou)**

Olive oil characterisation in relation to olive fruit maturity profile and olive fruit postharvest management



Olive oil constitutes the main product of olive culture. For the Mediterranean people, olive oil is the main source of oils and fats intake; furthermore, olive oil production and consumption is concentrated almost exclusively in the Mediterranean basin. It is derived from olive fruits (*Olea europaea* L.) of various varieties and its extraction from olive fruit requires a series of physicochemical processes.

The various quality standards for olive oil determine the different quality categories of olive oil, with virgin olive oils (extra virgin, virgin, ordinary) comprising the superior categories. The virgin olive oil categories reflect a wide range of variation in physicochemical and organoleptic characteristics. A repository of these characteristics with respect to varietal and edaphoclimatic origins can be an effective tool for product differentiation and for product quality control according to specific qualitative and sensorial consumer requirements. The lack of data concerning the physicochemical and organoleptic characteristics of varietal olive oils produced in Cyprus provided the springboard for launching the present ARI research programme on olive oil characterisation, a joint project of the Olive Technology Laboratory and the Postharvest Technology Laboratory. In this context, we examine the variety effect, the maturity effect as well as the effect of postharvest handling of olive fruits on the physicochemical and organoleptic characteristics of olive paste and olive oil. The main objectives of the project are: a) varietal characterisation of olive fruit ripening profiles, b) varietal characterisation of olive fruit postharvest behaviour, c) evaluation with respect to fruit harvest maturity and postharvest storage: i) efficiency of olive oil mechanical extraction; ii) rheological-chemical characteristics of the olive paste; iii) physicochemical organoleptic characteristics of the olive oil; iv) the oxidative stability of olive oil. **(M.G. Emmanouilidou, M.C. Kyriacou)**

CITRICULTURE

Citrus rootstock-scion relations on calcareous soils: Effects of citrus rootstocks on yield and quality characteristics of four citrus scion cultivars ('Delta' orange, 'Lane Late' navel orange, 'Nova' mandarin, 'Ortanique' hybrid)

The aim of the citrus rootstock evaluation programme is to identify rootstocks tolerant to the tristeza virus capable of replacing Sour Orange, the rootstock commercially used in Cyprus, which is highly susceptible to the virus. The commercial cultivars 'Delta' orange, 'Lane Late' navel orange, 'Nova' mandarin, 'Ortanique' hybrid were grafted on various rootstocks and cultivated on calcareous soils with the following main objectives: a) evaluation of rootstock effects on scion performance, b) evaluation of rootstock effects on scion fruit maturation profile, c) evaluation of rootstock effects on scion fruit quality characteristics. **(M.G. Emmanouilidou, M.C. Kyriacou)**

VEGETABLE CROPS

The Vegetable Crops Section undertakes research on intensive vegetable production systems, on the postharvest physiology and technology of horticultural commodities, and on the *ex situ* conservation and utilisation of local plant genetic resources. Current work in Vegetable Crop Science focuses on watermelon and melon rootstock-scion relations with respect to productivity, disease-resistance, stress response, quality and postharvest performance. The Vegetable Crops Section manages national participation in EU Cost Action 1204 (Vegetable Grafting to Improve Yield and Fruit Quality under Biotic and Abiotic Stress Conditions) and participates actively in the Action's working group on rootstock-mediated effects on vegetable fruit quality. Work on leafy salad crops examines the effect of planting pattern, nitrogen administration strategies, shading, seasonal adaptation and time of harvest on yield, quality, shelf-life and consumer safety. Performance of five male hybrid asparagus cultivars is under trial along with select populations of two wild asparagus species (*A. stipularis* and *A. acutifolius*) tested for adaptability to intensive cultivation.

The Postharvest Technology Laboratory (PTL) is the main analytical facility of the Vegetable Crops Section, dedicated to the study of pre- and postharvest ripening physiology of climacteric and non-climacteric fresh horticultural commodities in relation to the configuration of quality and postharvest performance. The PTL maps the farm-to-fork etiology of fresh produce quality, by studying the impact of pre- and postharvest applications on quality and shelf-life. Analytical emphasis is placed on assessing the implications of harvest maturity for product physiology, on deducing objective indices of physiological and commercial maturity, and on describing physicochemical attributes of quality. The effects of minimal processing on product quality and shelf-life, and the effectiveness of non-chemical postharvest treatments for controlling pathological and physiological loss of quality are also within the scope of PTL current activity. The PTL coordinates the current ARI project on the evaluation of an *ex situ* collection of indigenous pomegranate clones. The National Genebank constitutes another integral component of the Vegetable Crops Section concentrated on the collection, *ex situ* conservation, regeneration, characterisation, evaluation and utilisation of native plants of the flora of Cyprus and local landraces. Finally, the ARI Herbarium, which is an extension of the Genebank, is dedicated to the collection and documentation of botanical specimens of the Cyprus flora.

VEGETABLE SCIENCE

The occurrence of nitrates and nitrites in Mediterranean fresh salad vegetables and its modulation by preharvest practices and postharvest conditions

Winter and summer nitrate/nitrite concentrations in 11 salad vegetables were surveyed using a validated HPLC-DAD method. Nitrate was highest in rocket, both in winter ($\bar{x}=3974$ mg kg⁻¹ fw) and summer ($\bar{x}=3819$ mg kg⁻¹ fw). High nitrate accumulators included spinach, purslane, chards, dill, coriander and parsley. Wide intra-species variability and levels in excess of permitted maxima highlighted the importance of monitoring vegetable production methods to protect consumer health. Occurrence of detectible nitrite (14–352 mg kg⁻¹ fw) was most frequent in winter head cabbage. Three additional experiments examined the seasonal effects of nitrogen (N) fertilisation rate, application method, formulation and postharvest storage on nitrate and nitrite levels in lettuce, rocket and spinach. Violation of current nitrate limits is likely when total N exceeds 200 kg ha⁻¹, particularly in rocket and spinach. Postharvest nitrate reduction requires exogenous microbial nitrate reductase activity, which is unlikely to be achieved without visible loss of quality. (G.A. Soteriou, M.C. Kyriacou)



Iron biofortification of red and green pigmented lettuce in closed soilless cultivation impacts crop performance and modulates mineral and bioactive composition

Consumer demand for vegetables of fortified mineral and bioactive content is on the rise, driven by the growing interest of society in fresh products of premium nutritional and functional quality. Biofortification of leafy vegetables with essential micronutrients such as iron (Fe) is an efficient means to address the human micronutrient deficiency known as hidden hunger. Morphometric analysis, lipophilic and hydrophilic antioxidant capacities of green and red butterhead lettuce cultivars in response to Fe concentration in the nutrient solution (0.015 control, 0.5, 1.0 or 2.0mMFe) were assessed. The experiment was carried out in a controlled-environment growth chamber using a closed soilless system (nutrient film technique). The percentage of yield reduction in comparison to the control treatment was 5.7%, 13.5% and 25.3% at 0.5, 1.0 and 2.0mMFe, respectively. Irrespective of the cultivar, the addition of 1.0mM or 2.0mMFe in the nutrient solution induced an increase in the Fe concentration of lettuce leaves by 20.5% and 53.7%, respectively. No significant effects of Fe application on phenolic acids and carotenoid profiles were observed in green Salanova. Increasing Fe concentration in the nutrient solution to 0.5 mM triggered a spike in chlorogenic acid and total phenolics in red Salanova lettuce by 110.1% and 29.1% compared with the control treatment, respectively; moreover, higher accumulation of caffeoyl meso tartaric phenolic acid by 31.4% at 1.0 mM Fe and of carotenoids violaxanthin, neoxanthin and carotene by 37.0% at 2.0 mM Fe were also observed in red Salanova compared with the control (0.015 mM Fe) treatment. Red Salanova exhibited higher yield, P and K contents, ascorbic acid, phenolic acids and carotenoid compounds than green Salanova. The work shows how nutrient solution management in soilless culture could serve as effective cultural practices for producing Fe-enriched lettuce of premium quality, notwithstanding cultivar selection being a critical underlying factor for obtaining high-quality products. **(M.C. Kyriacou, G.A. Soteriou)**

Morphological and physiological responses induced by protein hydrolysate-based biostimulant and nitrogen rates in greenhouse spinach

Plant-derived protein hydrolysates (PHs) are gaining prominence as biostimulants due to their potential to improve yield and nutritional quality even under suboptimal nutrient regimens. In this study, we investigated the effects of foliar application of a legume-derived PH (0 or 4 mL L⁻¹) on greenhouse baby spinach (*Spinacia oleracea* L.) under four nitrogen (N) fertilisation levels (0, 15, 30, or 45 kg ha⁻¹) by evaluating morphological and colorimetric parameters, mineral composition, carbohydrates, proteins, and amino acids. The fresh yield in untreated and biostimulant-treated spinach plants increased in response to an increase in N fertilisation from 1 up to 30 kg ha⁻¹, reaching a plateau thereafter indicating the luxury consumption of N at 45 kg ha⁻¹. Increasing N fertilisation rate, independently of PH, lead to a significant increase of all amino acids with the exception of alanine, GABA, leucine, lysine, methionine, and ornithine but decreased the polyphenols content. Interestingly, the fresh yield at 0 and 15 kg ha⁻¹ was clearly greater in P-treated plants compared to untreated plants by 33.3% and 24.9%, respectively. This was associated with the presence in of amino acids and small peptides PH 'Trainer', which act as signaling molecules eliciting auxin- and/or gibberellin-like activities on both leaves and roots, and thus inducing a "nutrient acquisition response" that enhances nutrients acquisition and assimilation (high P, Ca, and Mg accumulation), as well as an increase in the photochemical efficiency and activity of photosystem II (higher SPAD index). Foliar applications of the commercial PH decreased the polyphenols content, but, on the other hand, strongly increased total amino acid content (+45%, +82%, and +59% at 0, 15, and 30 kg ha⁻¹, respectively) but not at a 45 kg ha⁻¹ rate. Overall, the use of PH could represent a sustainable tool for boosting yield and nitrogen use efficiency and coping with soil fertility problems under low input regimens. **(M.C. Kyriacou, G.A. Soteriou)**

Preharvest and postharvest evaluation of green asparagus male hybrid cultivars for intensive culture under local conditions

Green asparagus *Asparagus officinalis* cultivation presents unique features which render it potentially suitable as an alternative crop for Cyprus. It is a crop species considered highly tolerant to drought, however its irrigation requirements during the growth period of the fern (i.e. the above ground vegetative part) are linked to yield and quality. To examine the prospects of green asparagus cultivation in Cyprus, the Vegetable Crops Section of the ARI, in collaboration with the Horticulture Laboratory, Aristotle University of Thessaloniki, has set up an experimental trial on five promising male hybrids of green asparagus. Expected outputs of the experiment are: a) The determination of earliness, yield and quality of the physicochemical characteristics and postharvest performance of the five promising male asparagus hybrids, and b) evaluation of the hybrids as to their suitability for cultivation in arid climate. Preliminary results showed no differentiation among cultivars, concerning extra yield (tn ha⁻¹), total yield (classes extra & I), mean spear weight or extra spear number (**Table 3**). 'Giove' produced the lowest I (class I) yield and I spear number among the cultivars. No differences were recorded among the cultivars concerning classes extra and I spear weight. **(G.A. Soteriou, M.C. Kyriacou)**.

Table 3. Mean comparisons for asparagus category Extra and I spear number, spear yield and spear mean weight obtained from asparagus cultivars 'Eros', 'Giove', 'Vittorio', 'Italo' and 'Ercole'.

Cultivar	Spears (number per ha ⁻¹)			Yield (tn ha ⁻¹)			Spear weight (g)	
	Extra	I	Total	Extra	I	Total	Extra	I
	ns	**	ns	ns	**	ns	ns	ns
Eros	116683	351497 a	468180	2.8	4.2 a	7.0	23.5	11.9
Giove	143679	219414 b	363093	3.6	2.7 b	6.2	24.6	12.1
Vittorio	96571	389184 a	485755	2.3	4.7 a	7.0	23.8	12.0
Italo	111066	358564 a	469629	2.6	4.4 a	7.0	22.9	12.5
Ercole	99531	354155 a	453685	2.4	4.1 a	6.5	23.6	11.8

ns= non-significant effect; * significant effect at the 0.05 level; ** significant effect at the 0.01 level; *** significant effect at the 0.001 level. Values within columns followed by the same letter are not significantly different according to Tukey-Kramer HSD Test ($P < 0.05$).



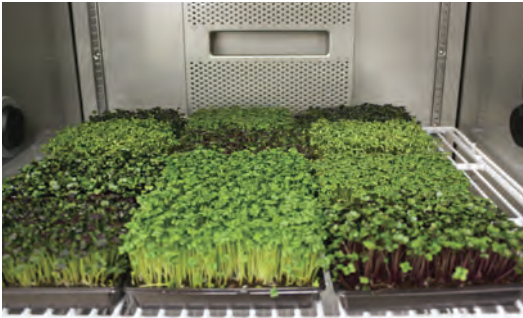
Adaptability and performance of two wild asparagus species (*A. stipularis* and *A. acutifolius*) under intensive cultivation: Comparisons between *in situ* and *ex situ* populations

The adaptability and performance of two wild asparagus species (*A. stipularis* and *A. acutifolius*) under intensive cultivation is examined. Both species are seasonally collected *in situ* and marketed in the Cyprus market as wild products. There has been no attempt to characterise the populations of wild species of the genus *Asparagus*, nor any extensive collection, *ex situ* conservation and study of seed germination physiology. Furthermore, there is no information on crop physiology, crop management, postharvest physiology, composition and physicochemical quality characteristics of these species. In order to generate this information, the Vegetable Section of the ARI has collected genetic material (seeds) of the two wild species from compact indigenous populations originated at five typical edaphoclimatic-botanical territories of Cyprus. Sample populations consisted of genetic material from 40 individual plants per territory. Subsequently seeds were treated under standard procedures as stated in ENSCONET (2009) protocol. Following seed collection, a germination protocol was established (percentage of success >90%) and seedlings were developed for the experimental setup at the Zygi Station. Presently, experimental plots have been established for *A. Officinalis* (five hybrids), *A. stipularis* (five populations) and *A. acutifolius* (two populations). (M.C. Kyriacou, A. Kyratzis, G.A. Soteriou).

POSTHARVEST TECHNOLOGY

Genotype-specific modulatory effects of select spectral bandwidths on the nutritive and phytochemical composition of microgreens

Advanced analytical data on microgreens' response to different light spectra constitutes a valuable resource for designing future crop-specific spectral management systems. The current study defined variation in productivity, nutritive and functional quality (mineral–carotenoid–polyphenolic profiles and antioxidant capacity) of novel microgreens (amaranth, cress, mizuna, purslane) in response to select spectral bandwidths (red, blue, blue-red) and appraised clustering patterns configured by the genotype-light-spectrum nexus. Growth parameters dependent on primary metabolism were most favoured by blue-red light's efficiency in activating the photosynthetic apparatus. Nitrate accumulation was higher under monochromatic light owing to the dependency of nitrite reductase on the light-driven activity of PSI, most efficiently promoted by blue-red light. Although mineral composition was mostly genotype-dependent, monochromatic red and blue lights tended to increase K and Na and decrease Ca and Mg concentrations. Lutein, β -carotene and lipophilic antioxidant capacity were generally increased by blue-red light putatively due to the coupling of heightened photosynthetic activity to increased demand for protection against oxidative stress; the disparate response however of purslane highlights the importance of genotype specificity in these responses and calls for additional investigation. Analysis of polyphenols by Orbitrap LC-MS/MS revealed substantial genotypic differences. Most



abundant phenolics were chlorogenic acid ($x = 5503 \mu\text{g g}^{-1} \text{dw}$), feruloylquinic acid ($x = 974.1 \mu\text{g g}^{-1} \text{dw}$), and caffeoyl feruloyl tartaric acid ($x = 993 \mu\text{g g}^{-1} \text{dw}$). Hydroxycinnamic acids accounted for 79.0% of the mean total phenolic content across species, flavonol glycosides for 20.7% and flavone glycosides for 0.3%. The general response across species was a decrease in individual polyphenolic constituents, particularly flavonol glycosides and total polyphenols under blue-red light. The pronounced effectiveness of monochromatic blue light in

eliciting synthesis of flavonoids could be linked to their capacity for absorbing shorter wavelengths thereby quenching generated photo-oxidation potential. The light-induced stimulation of the phenylpropanoid pathway by monochromatic blue light through epigenetic mechanisms or redox signaling in the photosynthetic apparatus warrants further investigation. The current work highlights how optimised genetic background combined with effective light management might facilitate the production of superior functional quality microgreens. (M.C. Kyriacou, G.A. Soteriou)

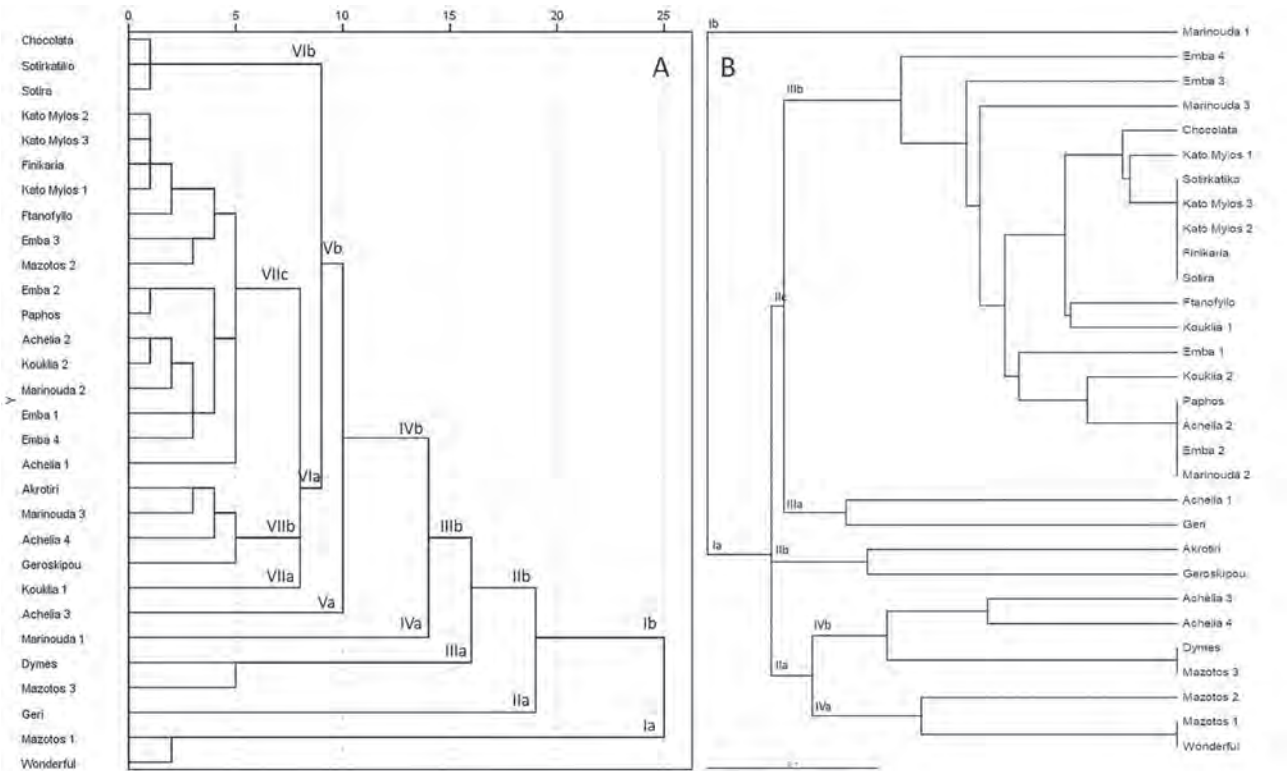
Functional quality in novel food sources: Genotypic variation in the nutritive and phytochemical composition of thirteen microgreens species

Compositional variation was examined across 13 microgreens species/subspecies representing Brassicaceae, Chenopodiaceae, Lamiaceae, Malvaceae and Apiaceae, grown in controlled environment. Macro-mineral concentrations were determined by ion chromatography, chlorophyll and ascorbate concentrations, and hydrophilic/ lipophilic antioxidant potentials by spectrophotometry, and major carotenoids by HPLC-DAD. Nitrate hyper-accumulators and wide genotypic differences in Na, K and S concentrations were identified. Antioxidant capacity was highest in brassicaceous microgreens and significant genotypic variation was demonstrated in chlorophyll and carotenoid concentrations. High phenolic content was confirmed in Lamiaceae microgreens, with significant varietal differences, and alternative phenolics-rich microgreens from the Apiaceae were identified. Twenty-eight phenolic compounds were variably detected and quantitated through Orbitrap LC-MS/MS with flavonol glycosides, flavones and flavone glycosides, and hydroxycinnamic acids representing 67.6, 24.8 and 7.6% of the mean total phenolic content across species, respectively. The obtained information is critical for selecting new species/varieties of microgreens that may satisfy demand for both taste and health. (M.C. Kyriacou, G.A. Soteriou)

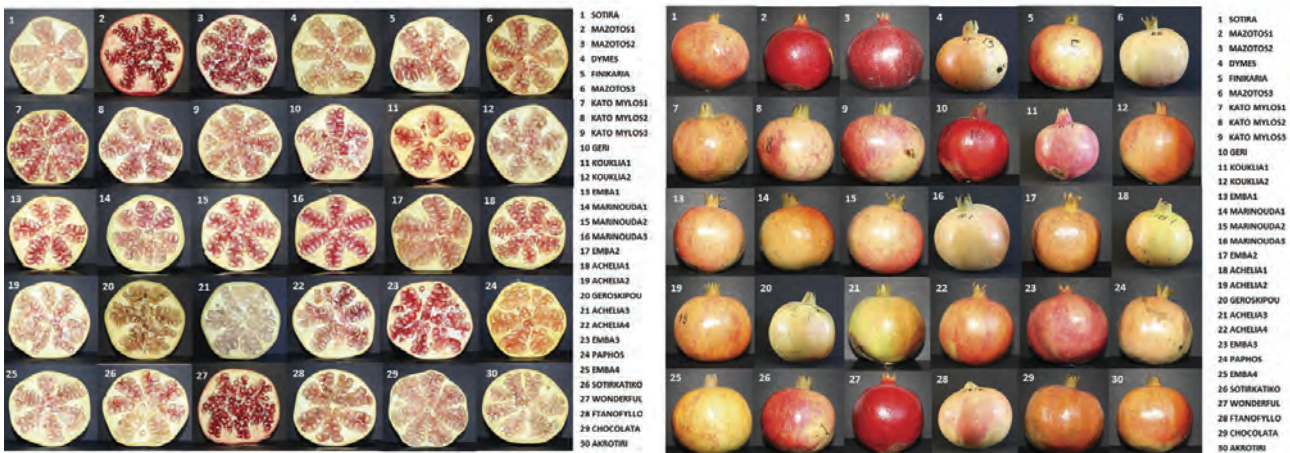
Physicochemical characterisation and trait stability in a genetically diverse *ex situ* collection of pomegranate (*Punica granatum* L.) germplasm from Cyprus

Proximity to the center of origin and geographical isolation shaped a unique genetic diversity of pomegranate in Cyprus that constitutes a valuable resource for the crop. Physicochemical characters and trait stability were studied for three years in an *ex situ* collection of 29 pomegranate accessions from Cyprus. Accession signature traits with exceptional yearly stability were titratable acidity and the citrate/malate ratio. Overall, the Cypriot germplasm was characterised by juice of low anthocyanin content ($\bar{x}=20.6 \text{ mg/L}$) and moderate phenolic content ($\bar{x}=613.0 \text{ mg/L}$) with glucose ($\bar{x}=69.1 \text{ g/L}$) and fructose ($\bar{x}=74.2 \text{ g/L}$) as predominant sugars. Juice antioxidant capacity was associated primarily with total phenolics and less so with juice colour and anthocyanin content. Total sugar content was higher in large-fruited accessions with darker juice. In most accessions the titratable acidity was low ($< 0.50\% \text{ w/v}$), with citric ($\bar{x}=44.7\%$), malic ($\bar{x}=39.1\%$) and succinic ($\bar{x}=15.8\%$) being the main organic acid fractions detected. Based on the maturity index (SSC/TA), six accessions were sweet-sour or borderline sweet-sour and 23 accessions were sweet. Cluster analysis of phenotypic characteristics and genetic data revealed a core group of thirteen genetically and phenotypically close accessions constituting the

Cypriot pomegranate landrace, characterised by moderate fruit weight, high juiciness, thin rind, moderately hard seeds and light-coloured juice, low in acidity, anthocyanins, phenolics and antioxidant capacity. The present work advances the understanding of genetic and environmental contribution to the configuration of pomegranate physicochemical fruit composition. (M.C. Kyriacou, A. Kyratzis)



A: Dendrogram of 30 pomegranate accessions based on squared Euclidean distances calculated on standardised mean phenotypic data across years. B: UPGMA dendrogram of 30 pomegranate accessions based on Jaccard genetic similarity.



Sensory and functional quality characterisation of protected designation of origin 'Piennolo del Vesuvio' cherry tomato landraces from Campania-Italy

Compositional characterisation was performed on seven 'Pomodoro del Piennolo del Vesuvio' (PPV) tomato landraces, a signature product of Campania (Italy) threatened by genetic erosion. Characterisation encompassed determinations of macro-minerals, soluble carbohydrates, starch, acidity, lycopene, polyphenols, anthocyanins, protein and free amino acids. Exceptionally high dry matter ($13.0 \pm 0.2\%$) and sugar content ($101.3 \pm 3.8 \mu\text{mol g}^{-1} \text{fw}$) and very low ($0.007\text{--}0.009$) Na/K ratio were invariably obtained across landraces, contrasted by significant variation in acidity ($28.5\text{--}3.9 \text{ g kg}^{-1} \text{dw}$). Giagiù, Acampora and Riccia San Vito differentiated by high polyphenols content ($131.8 \pm 2.5 \text{ mg } 100 \text{ g}^{-1}$) while Acampora, Cozzolino and Fofò by high lycopene content ($13.3 \pm 10.6 \text{ mg } 100 \text{ g}^{-1} \text{fw}$). Glutamate, GABA and glutamine represented 65% of the 22 detected amino acids mean total content. Glutamate, linked to umami taste, was highest ($19.2 \mu\text{mol g}^{-1} \text{fw}$) in Fofò. Our results will contribute towards the systematic documentation of sensory and functional quality profiles of an important collection of tomato landraces. **(M.C. Kyriacou)**

CONSERVATION OF PLANT GENETIC RESOURCES

National coordination

Cooperation with Biodiversity International, mainly through participation in the European Cooperative Programme for Plant Genetic Resources (ECPGR) and other international and national organisations continued. ARI is the National Focal Point in the European Internet Search Catalogue (EURISCO), the national correspondent for the FAO-World Information and Early Warning System on Plant Genetic Resources and the national representative to the Committee established by the Council Regulation 870/2004. It is also involved in the implementation, at the national level, of the International Treaty on Plant Genetic Resources for Food and Agriculture. **(A. Kyratzis)**

National Genebank (CYPARI)

Seed collection has focused on native plant genetic resources threatened by genetic erosion and on useful plants such as landraces and crop wild relatives. Around 46 new accessions have been collected during the last two years. Germination tests have been routinely conducted to assess germination capacity of the CYPARI conserved accessions.

Focus has been given to the development of germination protocols for plants of the flora of Cyprus. With collaboration of other organisations, the seed germination physiology of species of the genus *Aegilops* was investigated. It was found that different seed morphs differed significantly in terms of mass, final germination, germination timing, longevity estimates and antioxidant profile in most of the tested species. Small seeds germinated slower, had lower germination when left in their dispersal units, a higher antioxidant potential and were longer-lived than large seeds. The antioxidant gene expression varied between morphs, with different patterns across species but not clearly reflecting the phenotypic observations. The results highlight different trait trade-offs in dimorphic seeds of *Aegilops* and *T. urartu*, affecting their germination phenology and longevity, thereby resulting in recruitment niche differentiation.

Concerning *Sarcopoterium spinosum*, a study was conducted with collaboration of ENSCONET members, aiming to deepen the analysis of seed germination ecology and salinity tolerance of this species. The effect of the presence of the spongy issue varied among populations, with significant results for seed germination. For all populations, optimum germination temperatures were observed in the range of $10\text{--}20^\circ\text{C}$. Seeds of *S. spinosum*

showed the ability to germinate in up to 250 mM NaCl in the substrate, and their ability to recover after salt exposure may be interpreted as adaptation to the coastal habitats in which they generally grow. These results give this species a halo-tolerant character. Great interpopulation variability was detected in several aspects, which indicated that the Mediterranean populations of *S. spinosum* differ considerably and are adapted to their local conditions.

Genetic and phenotypic characterisation carried out on durum wheat genetic resources revealed a clear separation among modern varieties and landraces. Landraces presented the highest genetic variation (average discriminating power of= 0.89) and a high number of private alleles (131) was detected, underlying the unique genetic mark-up of this genepool. AMOVA revealed that the highest variability was detected within the landraces originating from Cyprus and landraces from the broader Mediterranean basin. The Cypriot landrace 'Kyperounda' was selected for further evaluation of its intra-genetic variation, and it was determined that genetic diversity was higher in accessions conserved as sublines (He 0.643–0.731) than bulks (He 0.384–0.469). Bayesian analysis revealed substantial admixture within 'Kyperounda' accessions, depicted also by Principal Coordinate Analysis. These findings emphasise that high intra-genetic diversity is retained when landraces are conserved as sublines in *ex situ* collections, while landraces that are conserved as bulks have a higher risk of bottleneck. Hence, a more exhausting diversity evaluation is needed in order to fully utilise landraces in breeding schemes and to prevent the loss of genetic variation.

Accessions of *Avena ventricosa* Balansa ex Coss., a species that is considered the C-genome donor of the cultivated hexaploid oat and is a 'priority' species for conservation, since it has limited geographic distribution and the only recorded populations in Europe are present in Cyprus, was selected for investigating its genetic variability. It was revealed that the genetic variety was mainly allocated among the populations, since clustering obtained was according to the geographic origin of the samples and the habitat. Species distribution modeling showed that the most important climatic variable defining *A. ventricosa* distribution is the mean diurnal temperature. Furthermore, significant association of the genetic structure to environmental variables was detected; overall, a negative association to precipitation was confirmed, while significant correlations of genetic structure and the temperature at the time of anthesis and germination were established. (A. Kyratzis)

Conservation actions for threatened Mediterranean-island flora: *ex situ* and *in situ* joint actions

CARE-MEDIFLORA aimed to improve the conservation status of threatened plant species of the Mediterranean. It was a project implemented by institutions of six Mediterranean islands and the IUCN/SSC Mediterranean Plant Specialist Group. The institutions involved were jointly addressing short-term and long-term conservation needs:

- *In situ* conservation of endangered plant species of the Mediterranean islands through *in situ* management actions such as population reinforcement, species reintroduction, fencing, controlling pest plants and reconnecting isolated remnants.
- *Ex situ* conservation of endangered plant species through seed collection and long-term storage in seed banks of accessions representative of the overall diversity within selected taxa. Previous and new seed collections were used to produce plant material for *in situ* management actions.

The project supported networking among the project partners, institutions and authorities on each island and/or related initiatives at Mediterranean and wider international level, in order to contribute to the long-term effectiveness of plant conservation. Project results were shared with plant conservation specialists and local

stakeholders with the aim to increase collaboration among institutions involved with *in situ* and *ex situ* conservation and to raise awareness about local flora vulnerability. *In situ* conservation actions were applied for 10 rare plants of the flora of Cyprus, 121 accessions were collected and *ex situ* conserved, and germination protocols were developed for most of the species collected. The project was founded by *MAVA foundation pour la Nature* and it was ended in 2019. **(A. Kyratzis, M.C. Kyriacou)**

Carobs, the black gold of Cyprus: Science meets industry – BLACKGOLD

The overall major objective of the project is to help re-mobilise and extend the carob industry in Cyprus into new and innovative food and nutrient supplement products that meet the needs of the growing international market for carob-based products. This objective of re-establishing the carob economic sector in Cyprus will be based on the in-depth scientific analysis of key market valued properties possessed by carobs in Cyprus.

The sector is responsible for the characterisation of the genetic, morpho-physiological and compositional variability of local carob genetic resources (Work package 3). Such information is crucial for the conservation of the species and the selection of most promising genotypes for cultivation to the appropriate environments. This will be accomplished through: (1) genotyping and phenotyping of indigenous carob genetic resources from the main agroecological zones of Cyprus where carobs are traditionally cultivated, (2) evaluation of the comparative contribution of genotype and environment effects on the variance of agronomic and technological traits, (3) characterisation of morphological, physiological and compositional changes with respect to carob fruit on-tree ripening and postharvest storage. **(A. Kyratzis, M.C. Kyriacou)**



ANIMAL PRODUCTION

Research in the Animal Production Section focuses on the topics of nutrition, management, animal breeding and physiology of reproduction. All projects are ultimately directed towards increasing milk and meat yields under semi-intensive or intensive management systems in sheep, goats and dairy cattle. In addition, genetic methods and animal husbandry practices are employed, aiming at preventing and controlling animal diseases. Research work on animal breeding aims at improving the genetic stock with respect to important economic traits using within-breed selection methods. Genetic evaluations are based on selection indices that combine individual capacity of young animals for growth and milk production of female ancestors. This method is routinely used for the evaluation and selection of superior breeding stock in sheep and goats. Research in genetic improvement is also directed toward dissecting the genetic aspects underlying production traits, including further characterisation of scrapie genotypes and productive output in goats. Research programmes in the area of reproductive physiology of farm animals examine genetic and environmental factors that influence seasonal reproduction, reproductive development and puberty in sheep and goat breeds, under local conditions. In farm management, artificial rearing systems are evaluated, with automated feeders and milk substitute being used for lambs and kids from birth to weaning.

A research project employing genetic methods to combat the scrapie disease in Chios sheep has been successfully implemented by ARI in cooperation with the Veterinary Services. The Cyprus Chios sheep unit of ARI at Athalassa Experimental Farm has been transformed into a nucleus herd of scrapie-resistant genotypes. The number of productive animals at the nucleus is maintained at around 350 breeding females. Further research in genetic improvement at ARI is directed toward dissecting the genetic aspects underlying production traits, and further characterising scrapie genotypes in goats. A programme is currently in progress to transform the Cyprus Damascus goat herd at ARI into a nucleus of scrapie-resistant genotypes. The project continued in 2018 and 2019, aiming at creating a nucleus of 300 breeding goats that would be resistant to the disease. This has enabled ARI to issue scrapie-resistant animals to the farmers, which contribute significantly in eradicating scrapie from the Cyprus goat population.

The ARI Dairy Cattle Unit

The Friesian/Holstein dairy cattle unit of ARI is situated at Athalassa. The performance of cows during the years 2018 and 2019 is shown in **Table 4**. The overall performance of the herd was satisfactory, since milk yield per annual cow was on average 9,019 in 2018 and 7,970 in 2019. The total milk produced on farm was 380,604 in 2018 and 348,317 in 2019. Good reproductive management led to no abortions in 2018 and 2019. Mastitis incidence has improved significantly during 2018-19. **(G. Hadjipavlou, D. Sparaggis)**

Genetic evaluation and selection to further improve the performance of Cyprus Chios sheep and Damascus goat nucleus herds at ARI

The ARI small ruminant herds consist of 350 Cyprus Chios sheep and 300 Cyprus Damascus goats. Daily milk yield is recorded automatically during milking, and this led to improved phenotyping for genetic evaluations. Male and female replacement stock is selected on the basis of a continuously updated index combining 60-day milk yield of dam and grand dam and individual body weight at 98 days of age for lambs and at 120 days for kids. The breeding scheme is updated yearly and directed toward minimal inbreeding for both sheep and goats. Mating takes place two times per year for each species. Production and reproduction characteristics during the period 2018/19 are shown in **Tables 5 and 6**. **(G. Hadjipavlou)**



The effect of artificial rearing on kid growth and milk production of Cyprus Damascus goats

Research on zero suckling systems in Cyprus Chios ewes and Cyprus Damascus goats continued in 2018 and 2019. Lambs and kids on zero suckling were reared artificially on milk substitute using four automatic milk-feeding machines. Yearling Damascus goats were allocated as they kidded to either Natural Suckling (NS) or were separated from their kids immediately after birth. NS goats suckled up to two kids, while separated kids were Artificially Reared (AR) on milk replacer. Colostrum was given to AR kids by bottle-feeding. All kids were weaned at 49 ± 3 days of age. AR goats were milked twice daily. NS goats were milked once daily before and twice daily after weaning. Results in 2018 and 2019 further supported findings from previous years that artificially reared kids had satisfactory pre-weaning growth, although slightly lower than that of suckling kids; however, both groups reached the same final weight at 120 days of age. Goats on zero suckling produced more marketable milk over their whole lactation period than suckling goats. Therefore, in particular to dual-purpose breeds such as the Damascus one, artificial rearing may increase the farmer's income with no adverse effects on kid growth. (G. Hadjipavlou)

Effects of whole, cracked, and steam-flaked corn on growth performance in feedlot Damascus goats

The experiment ran in 2018 and was a joint research project between the Agricultural Research Institute and the Cyprus University of Technology. The effects of corn processing and of concentrate mixture type were studied on weaned Damascus breed kids of 70 days of age. Sixty animals were divided into four groups on the basis of live-weight and age, and randomly allocated to one of the following treatments (type of concentrate mixture): (1) pelleted concentrates (P), where all ingredients were ground and pelleted in 5-mm cubes; (2) dry-rolled corn grains (DRC); (3) whole-grain corn (WGC); (4) steam-flaked corn (SFC), mixed with pellets made from the other ingredients of the concentrate mixture. Diets of all four groups were formulated to be iso-energetic, with corn comprising 707/kg of the concentrate mixture, and offered *ad libitum* along with 0.1 kg per head of Lucerne hay. Treatment effects on feedlot kid performance were evaluated in a seven-week trial, with measurements of live weight gain, feed consumption and rumen pH.

Animals fed SFC presented lower ($P < 0.05$) feed consumption and lower ($P < 0.05$) average daily gain when compared to the other three groups. Animals fed WGC, DRC and P diet showed similar ($P > 0.05$) growth rates and feed consumption. Feed efficiency and pH measurements were similar ($P > 0.05$) across treatments, and, therefore, the lower live-weight gained in SFC animals was attributed to lower feed consumption. **(D. Sparaggis)**



Genetic and molecular techniques for controlling the scrapie disease in sheep and improving the genetic stock provided to farmers

Combating scrapie disease in Chios sheep with the use of genetic and molecular methods is a joint project of the ARI Animal Production and Agrobiotechnology Sections. The present population of the ARI unit consists of breeding ewes and rams of the scrapie-resistant ARR/ARR genotype. For breeding purposes, the number of resistant rams and ram lambs issued to farmers in the period of 2018-2019 was 48 and 154, respectively, and that of surplus female lambs was 151. By increasing the frequency of the desirable allele in Cyprus Chios sheep, and consequently of the resistant genotypes in the population, the disease has been controlled and will be eventually eradicated. It should be emphasised that the project for controlling scrapie in Chios sheep runs in parallel with the project aiming at the genetic improvement of economically important traits (milk yield, growth, prolificacy etc.). Additionally, since 2008, genetic management of the sheep nucleus unit has been significantly upgraded, in an effort to substantially minimise inbreeding that arose out of necessity during the effort to eradicate the scrapie-susceptible genotype (AQQ/AQQ) from the flock. **(G. Hadjipavlou, I.M. Ioannides)**

Genetic and molecular techniques for controlling the scrapie disease in goats and improving the genetic stock to be provided to farmers

The programme for controlling the scrapie disease in goats runs in the framework of ARI-funded joint research between the Animal Production and Agrobiotechnology Sections, and in cooperation between the ARI and the Veterinary Services. During 2016-2017, the collection of genetic and production information for Damascus goats continued, with the aim of further studying the different *PrP* genotypes in goats and compiling enough phenotypic information to examine potential associations between genotype and production characteristics of the animals. Targeted matings were designed and performed in both breeding seasons of each year in order to increase the frequency of the D and S alleles at codon 146 of the *PrP* gene, and simultaneously decrease the N allele at the same locus. In 2018 and 2019, molecular genotyping of the selected *PrP* alleles was conducted

by the Agrobiotechnology laboratory on more than 528 animals. In this period, the Animal Production section provided the farmers with 51 bucks, 50 goats, 133 male kids and 99 female kids. All the animals had proposed scrapie-resistant genotypes, in order to decrease the frequency of the assumed scrapie-susceptible N allele in the Cyprus Damascus goat population. For all genotype classes, records on body weight at birth, at weaning and at 120 days from birth, dam prolificacy and milk production have been collected to examine potential associations between genotype and animal production traits. All information is recorded in an extended, continuously updated database, according to standard procedures of the Animal Production section. (**G. Hadjipavlou, I.M. Ioannides**)

Research project on the establishment of a “CYprus AGRicultural Genomics cENTre” (AGRICYGEN)

The European Project **AGRICYGEN** phase 1 (CYprus AGRicultural Genomics CENTre) commenced in 2017 and ran until the 31st of August 2018. The project was funded by the Teaming (Phase 1) call of the Horizon 2020 framework programme and was coordinated by the Agricultural Research Institute. AGRICYGEN aimed at establishing a Center of Excellence in Animal and Plant Production in Cyprus. AGRICYGEN encompassed a pioneering research collaboration between the Agricultural Research Institute, the Cyprus Institute, the Cyprus Institute of Neurology and Genetics, the Cyprus-based Development Organisation, RTD TALOS LTD, alongside leading research institutions in Europe. Specifically, the Consortium’s Advanced Partners are the University of Edinburgh (UK), the National Institute for Agricultural Research (INRA) (France) and the Institute for Plant Genetics and Crop Plant Research (IPK) (Germany), all experts in various fields in Agrigenomics. The advanced partners provided the necessary background and know-how to develop a thorough business plan in order to establish the Center of Excellence in Cyprus.

The AGRICYGEN project aims at the establishment of a Center of Excellence in Cyprus, which will take advantage of cutting-edge technologies and expertise in order to facilitate:

- a) Increased milk production from local sheep and goat breeds
- b) Increased production of local ruminant feed
- c) The ecological enrichment of Cyprus soils

The project outcomes will have direct impact on the Cyprus economy and society, and will significantly contribute to sustainable development of agriculture and animal production on the island. The initial focus of the project will be on employing research approaches for fulfilling the halloumi cheese PDO requirements in small ruminant milk and feed production, within the harsh and fluctuating environmental and climatic conditions of Cyprus. AGRICYGEN will also aim at further advancing research and innovation activities in various domains connected with the primary production sector.

In conjunction with the International Climate Change conference organised in Lefkosia, Cyprus on the 18-19th May 2018, a pre-conference workshop was organised by the AGRICYGEN project partners and featured some high-level attendances. This workshop took place on the 17th of May 2018, and had the title: “Agriculture and Animal Husbandry in a Changing Climate”. During the workshop, the AGRICYGEN research activities that aim at addressing and mitigating the climate change effects on agriculture and animal husbandry were presented, along with interesting cutting-edge research results from AGRICYGEN and non-AGRICYGEN scientists in Cyprus and abroad. The presentations covered three thematic areas, linked to the project: a) Genomics and breeding in a changing climate, covering both animals and plants, b) Crop production in a changing environment, and c) Soil microecology and greenhouse gas emissions.

During Teaming Phase 2 proposal submission and evaluation, AGRICYGEN ranked high (number 19th out of 46 proposals submitted), yet it did not receive EC funding. However, its implementation has been approved to commence in 2021 through 100% government funding, via a Council of Ministers Decision, published on the 27th of November 2019 (Decision Number 88.605). (**G. Hadjipavlou, D. Fasoula, M. Omirou, I.M. Ioannides**)

The AGRICYGEN project received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 763700



Table 4. Performance of dairy cattle at the ARI, Athalassa Experimental Farm

Variable	Year	
	2018	2019
Cows calved	23	28
Heifers calved	19	19
Abortions	0	0
Calves born alive	42	45
Calves born dead	2	3
Calves died	3 (0.07%)	1 (0.02%)
Calving interval (days)	389	412
Days open	112.4	134.0
Duration of pregnancy (days)	277	278
Services/conception	1.80	1.72
Annual cows	42.2	43.7
Milk produced (l)	380,604	348,317
Milk/annual cow (l)	9,019	9,142
Milk fat %	3.45	3.65
Milk protein %	3.49	3.53

Table 5. Production characteristics of Chios ewes at ARI (2018/19)

Trait	Yearlings	Adults
No. of ewes lambing	110	350
Lambs born/ewe	1.69	2.06
Lambs born live/ewe	1.53	1.86
Litter weight at birth (kg/ewe)	5.77	6.88
Lambs weaned/ewe	1.47	1.71
Litter weight at weaning (kg/ewe)	16.9	21.5
60-day milk (kg/ewe)	114	135
Total milk (kg/ewe)	362	460
Days in milk	214	263
Milk fat (%)	5.46	6.03
Milk protein (%)	4.85	5.29

Table 6. Production characteristics of Damascus goats at ARI (2018/19)

Trait	Yearlings	Adults
No. of goats kidding	108	241
Kids born/goat	1.57	1.95
Kids born live/goat	1.53	1.87
Litter weight at birth (kg/goat)	5.80	7.89
Kids weaned/goat	1.34	1.69
Litter weight at weaning (kg/goat)	15.8	23.5
60-day milk (kg/goat)	89	119
Total milk (kg/goat)	418	520
Days in milk	183	205
Milk fat (%)	4.27	4.46
Milk protein (%)	3.48	3.88

PLANT PROTECTION

Scientific work in Plant Protection concern research studies in Plant Pathology and Entomology. Specialised studies are conducted to address major crop protection problems associated with particular virus and virus-like diseases, prokaryotic microorganisms and insect pests. Joint multi-disciplinary research projects are undertaken, targeting various important pests and diseases of cultivated vegetable and fruit tree crops. All research activities are governed by the considerations of sustainability in crop protection and production, food quality and safety, environmental protection and the utilisation of new technologies for the development of more effective crop protection practices. Plant Pathology research includes the implementation of modern nucleic acid diagnostic assays for plant pathogens. Research effort has been focused on the development of effective detection tools in order to identify the phytosanitary status of plants, for certification and quarantine purposes.

In line with the above principles, one of the main activities of the Section concerns the development of integrated pest management (IPM) strategies, based on various combinations of ecosystem-oriented methods, i.e. biological control, cultural practices, natural products, resistant varieties, resistant rootstocks and minimal use of selected, mild pesticides. This approach ensures sustainability and minimises pesticide risk to human health and the environment. It can be applied alone or in combination with other ecosystem-oriented production practices, in the context of an advanced system of sustainable agriculture, known as integrated crop management (ICM). Studies to develop IPM/ICM systems were carried out on citrus, grapevines and on vegetable and ornamental greenhouse crops, in cooperation with other Sections of the Institute.

Plant Pathology and Entomology laboratories provided support for the scientific identification of plant diseases and insect pests, in various samples provided by the Department of Agriculture, the Medical and Public Health Services, the Department of Forestry, agriculturists from the private sector and farmers.

PLANT PATHOLOGY

Programme for the control and characterisation of *Citrus tristeza virus*

The programme for the control of CTV was initiated in 1992, with main aims the systematic survey of all citrus and the removal of infected trees and/or groves wherever that was feasible. The survey has been conducted by indexing 10-20% of the trees of each grove and samples were tested in the Plant Virology Laboratory by Enzyme-



linked immunosorbent assay (ELISA). Disease incidence ranged in the different districts from 2.33% to 18.3%. The highest proportion of infected trees and groves was noted in the districts of Ammochostos and Lemesos. Field symptoms of CTV-infected trees varied from mild to severe, while some infected trees were symptomless. The most intense symptoms were noted on Marsh seedless or Star Ruby grapefruit and included stunting, chlorosis, fragility and dieback of twigs, pitting of branches and general decline. CTV caused severe decline and death of 40 to 50-year-old grapefruit and Valencia orange trees in certain groves in the districts of Ammochostos and Lemesos. With regard to the greenhouse indexing tests,

usually the intensity of field symptoms related well to the severity of CTV symptoms on Mexican lime in the greenhouse. No seedling yellows symptoms on sour orange or grapefruit were observed. **(L.C. Papayiannis, T. Kapari-Isaia)**

Molecular characterisation of *Citrus tristeza virus* isolates

Several isolates collected from different areas of Cyprus causing a wide diversity of symptoms were tested and characterised. Symptoms on field trees ranged from inconspicuous to twig die-back, decline and death of sweet orange or grapefruit trees on sour orange rootstock. Similarly, on Mexican lime, symptoms ranged from barely noticeable leaf-vein clearing to vein corking, stem pitting and plant stunting. Coat protein gene (CPG) amplicons were digested by a selection of restriction enzymes and characterised with single-strand conformational polymorphism. The nucleotide sequence of the CPG was determined and phylogenetic analysis was performed. Results showed that most symptomless isolates from Cyprus clustered among the mild strains reported from Spain, Portugal and Africa. In addition, isolates that were responsible for decline of sweet orange, grapefruit and mandarin trees showed high similarity with strains reported in Africa (B249), whereas four other isolates that caused stem pitting symptoms clustered with T36, an American severe strain from Florida. The RFLP and SSCP techniques and the subsequent nucleotide analysis of the Cypriot CTV isolates enabled their clear distinction in mild and severe, their comparison to universal isolates/strains. The molecular techniques used in the present work enabled, in addition to the differentiation of mild and severe isolates, the establishment of relationships of Cypriot isolates to universal isolates, including the severe isolates T36 and T3 from Florida, B246 from South Africa, B-CTV from India and the mild isolate 28C from Portugal. These results substantiate our belief that CTV was introduced in Cyprus with imported budwood from South Africa in the 1930's when there was not much knowledge about viruses, and, more recently, from other countries, as travelling became easier during the last three decades. **(L.C. Papayiannis, T. Kapari-Isaia)**

Citrus rootstock evaluation for tolerance to Cypriot isolates of *Citrus tristeza virus*

The main goal of this project was to investigate tolerant rootstock for replacement of the CTV-sensitive sour orange, which is commercially used in Cyprus. Twenty-four plants of the following citrus rootstocks were grafted



with Washington Navel sweet orange and are being evaluated for their tolerance to CTV in a replicated complete block design, at Xylotymbou experimental Station of the Institute: Carrizo citrange, Swingle citrumelo, Volkameriana lemon, Gou Tou, Cleopatra mandarin and Sour Orange. Half of these trees were graft-inoculated with CTV and the rest kept healthy. Infected and healthy trees are being evaluated and compared with regard to their performance in the field, fruit production and quality. Most of the trees grafted on citrumelo rootstock showed severe stunting and chlorosis. **(T. Kapari-Isaia, L.C. Papayiannis)**

Citrus certification programme

A mandatory certification programme has been established and functioning since the mid 1990's. The responsibility for the implementation of the relevant legislation rests with a seven-member Board under the Minister of Agriculture. The foundation or pre-basic block is kept and maintained under insect-proof screen by the Agricultural Research Institute, whereas the multiplication and mother blocks, protected also under insect-proof screen, are maintained by the Department of Agriculture. In addition, the private nurseries are obliged to keep their mother plants and the production of seedlings and budded treelets also under screen. The foundation block provides with virus-tested material the mother blocks of the Department of Agriculture, which in turn provide with budwood the private nurseries or directly the growers. Citrus budwood, which is introduced from overseas sources, is kept in a post-entry quarantine station and undergoes thorough indexing for the known virus and virus-like diseases before entering the foundation block. Local varieties are being cleaned from the known virus problems by micrografting. All virus-free material, which was either selected, or imported by the Horticulture Section of the Institute or produced locally so far by micrografting, is maintained in a pre-basic plantation under double insect-proof screen at the Agricultural Research Station of Zygi. To the present 60 citrus accessions are included in the plantation and are kept in clean state by application of strict sanitary measures and regular indexing, in conjunction with optical observation for either fungal problems or genetic aberrations. The plantation provides with citrus material the basic or mother plantations of the Department of Agriculture and the experimental glasshouses of the Institute. **(T. Kapari-Isaia, L.C. Papayiannis)**

Production of healthy local citrus propagating material

For several commercial varieties, it is possible to reintroduce presently healthy material from overseas Citrus Production Centers. However, this always includes the risk of the introduction of new unknown diseases. In addition, for local varieties there is not such possibility. For these reasons, it was decided to employ contemporary techniques, as micrografting *in vitro* to free from virus and other disease problems valuable local citrus varieties and/or clones, including 'Lapithou' and 'Polyphori' lemon, 'Arakapa' mandarin, local 'Jaffa' orange and others. The micrografting *in vitro* technique was used in Cyprus since 2000 to free from virus and other pathogens valuable local citrus varieties and/or clones. A survey in commercial groves was conducted for selection of elite mother plants of citrus, including 'Polyphori' and 'Lapithou' lemon (*Citrus limon* Burm f.), 'Jaffa', 'Siekeriko' and 'Aematoyisiki' orange (*C. sinensis* L.), 'Arakapas' mandarin (*C. reticulata* Blanco), 'Frappa' (*C. grandis* (L.) Osbeck), 'Bergamot' (*C. bergamia* Risso & Poit.), 'Coumantantas' (*C. comandatore*) and 'Pummelo' (*C. maxima*). All mother plants were tested for viruses and viroids by biological indexing, by ELISA for CTV, and by RT-PCR for viroids. The standard procedure of shoot-tip grafting technique was used for elimination of viroids and CPsV in the selected citrus isolates. Micrografted plants, re-grafted on sour orange seedlings *in vivo*, and successfully established and transferred to the glasshouse, were tested 6-9 months later for the viruses and viroids present in meristem donor mother plants. **(T. Kapari-Isaia, L.C. Papayiannis)**

Elimination of citrus pathogens from infected citrus plants by micrografting *in vitro*

In vitro micrografting technique has been used for sanitation of citrus species and varieties infected by *Citrus tristeza virus* (CTV) and/or citrus viroids. Several citrus tree varieties including the lemon varieties 'Adamopoulou' and 'Verna' and the mandarin varieties 'Clasuelina' and 'Page' were selected. All trees were tested for viruses and viroids by biological indexing, by ELISA for CTV and CPsV, and by RTPCR for viroids. They were all found free of CPsV, CVV, concave gum and impietratura. The micrografting technique *in vitro* was used for elimination of viroids and CTV in the selected citrus isolates. Micrografted plants were re-grafted on sour orange seedlings *in vivo*, or were potted and those which were successfully established were transferred to the glasshouse. They were tested 6-12 months later for CTV and viroids present in meristem donor mother plants. One or more plants produced by micrografting from all mother plants were found free of CTV and/or viroids. **(T. Kapari-Isaia, L.C. Papayiannis)**

Citrus viroids research

Citrus viroids are listed among the most important pathogens that negatively affect the citrus industry worldwide. They are highly transmitted by grafting and other mechanical means. An extensive survey was conducted in Cyprus during 2015-2018 in order to identify the presence and incidence of citrus viroids using molecular based techniques, and, in selected samples, biological indexing. TaqMan assays were developed, evaluated and used for the detection of five citrus viroids. Results showed that *Citrus exocortis viroid* (CEVd) was the most widespread viroid with an incidence of 82%, followed by *Hop stunt viroid* (HSVd), which was detected in 55% of the 1,280 samples tested. Citrus bent leaf viroid (CBLVd), *Citrus dwarfing viroid* (CDVd) and *Citrus bark cracking viroid* (CBCVd) were also identified at lower rates of 14, 10 and 8%, respectively. CEVd+HSVd was the most common viroid combination (70%), while CEVd+CBLVd, CEVd+CDVd and CEVd+CBCVd were detected at 11, 10 and 9.5% of the double viroid mixtures (25%). Triple viroid combinations were also recorded at 10% of the tested samples with CEVd and HSVd identified in all mixtures. *Citrus viroid V* was not detected in Cyprus. Sequencing analysis showed that all HSVd shared 100% nucleotide identity and were closely related to other isolates from the Mediterranean Basin, while CEVd isolates shared 97-100% homology to exocortis isolates from neighbouring countries, including Africa and Asia, suggesting multiple introductions through contaminated budwood. Only 7.5% of the samples tested were negative to viroid infection, indicating the need for dissemination of virus/viroid-free propagating material. **(L.C. Papayiannis, T. Kapari-Isaia)**

Evaluation of five new sour orange hybrid rootstocks for tolerance to citrus viroids

Five citrus hybrid rootstocks are evaluated at Zygi Experimental Station for their tolerance to citrus viroids. The five citrus hybrids are the following: (1) Sour orange × Orange (*Citrus aurantium* L. × *Citrus sinensis*, (L.) Osbeck), (2) Sour orange × Satsouma (*Citrus aurantium* L. *Citrus reticulata* blanco), (3) Sour orange × Citrumelo 1452 × Lemon (*Citrus aurantium* L. × *P. trifoliata* (L.) Raf × *Citrus paradisi* Macf. × *Citrus limon*), (4) Sour orange × Volkameriana (*Citrus aurantium* L. × *Citrus volkameriana*) and (5) Sour orange × Carrizo (*Citrus aurantium* L. × *Citrus sinensis* (L.) × *Poncirus trifoliata* (L.) Raf). **(T. Kapari-Isaia, L.C. Papayiannis)**

In vitro techniques for elimination of pathogens in infected Citrus

In vitro micrografting, chemotherapy and cold therapy techniques have been used for sanitation of citrus species and varieties infected by *Citrus tristeza virus* (CTV) and/or citrus viroids. Several citrus tree varieties, including the lemon varieties 'Adamopoulou', 'Verna', 'Polyphori' and 'Lapithou', the orange varieties 'Navelina', 'Washington navel', 'Jaffa', 'Siekeriko' and 'Aematousiki', the mandarin varieties 'Clasuelina', 'Page' and 'Arakapas', 'Frappa' and 'Bergamot' were selected. Four Mexican lime (ML) trees infected by severe or mild CTV isolates from Cyprus were used. All trees were tested for viruses and viroids by biological indexing, by ELISA for CTV and CPsV, and by RT-PCR for viroids. They were all found free of CPsV, CVV, concave gum and impietratura. Thirteen trees were infected by CEVd and/or other viroids and one was infected by both CTV and viroids. The micrografting technique *in vitro* was used for elimination of viroids and CTV in the selected citrus isolates. Chemotherapy *in vitro* was tested in ML trees infected by CTV. Coldtherapy *in vitro* was tested in Lapithou lemon tree infected by CEVd and HSVd. Micrografted plants were re-grafted on sour orange seedlings *in vivo*, or were potted, and those which were successfully established were transferred to the glasshouse. They were tested 6-9 months later for CTV and viroids present in meristem donor mother plants. One or more plants produced by micrografting from all mother plants were found free of CTV and/or viroids. Elimination of CTV on apical meristems was achieved by chemotherapy *in vitro* using 30, 40 and 50 mg/lit ribavirin or 30, 40 and 50 mg/lit methotrexate. Elimination of viroids by coldtherapy at 10 C for 5 weeks was not possible, but was successful by coldtherapy at 4 C for 5 weeks. **(T. Kapari-Isaia, L.C. Papayiannis)**

Citrus rootstock evaluation for tolerance to Cypriot isolates of *Citrus tristeza virus*

The main goal of this project was to investigate tolerant rootstock for replacement of the CTV-sensitive sour orange, which is commercially used in Cyprus. Twenty four plants of the following citrus rootstocks were grafted with Washington Navel sweet orange and are being evaluated for their tolerance to CTV in a replicated complete block design, at Xylotymbou experimental Station of the Institute: Carrizo citrange, Swingle citrumelo, Volkameriana lemon, Gou Tou, Cleopatra mandarin and Sour Orange. 50% of these trees were graft-inoculated with CTV and the rest remained healthy. Infected and healthy trees are being evaluated and compared with regard to their performance in the field, fruit production and quality. Most of the trees grafted on citrumelo rootstock showed severe stunting and chlorosis. **(T. Kapari-Isaia, L.C. Papayiannis)**

Evaluation of five new sour orange hybrid rootstocks for tolerance to citrus viroids

Five citrus hybrid rootstocks are evaluated at Zygi Experimental Station for their tolerance to citrus viroids. The five citrus hybrids are the following: (1) Sour orange × Orange (*Citrus aurantium* L. × *Citrus sinensis*, (L.) Osbeck), (2) Sour orange × Satsouma (*Citrus aurantium* L. *Citrus reticulata* blanco), (3) Sour orange × Citrumelo 1452 × Lemon (*Citrus aurantium* L. × *P. trifoliata* (L.) Raf × *Citrus paradisi* Macf. × *Citrus limon*), (4) Sour orange × Volkameriana (*Citrus aurantium* L. × *Citrus volkameriana*), and (5) Sour orange × Carrizo (*Citrus aurantium* L × *Citrus sinensis* (L.) × *Poncirus trifoliata* (L.) Raf). **(T. Kapari-Isaia, L.C. Papayiannis)**

Production, maintenance and distribution of healthy stone fruit material

Virus-free material is maintained in a pre-basic plantation under insect-proof screen at the Zygi and Saittas Experimental Stations. Currently, 52 stone fruit accessions are included in either plantation, kept in sanitary condition by application of strict measures and regular indexing, in conjunction with optical observation for either fungal problems or genetical aberrations. The plantations provide with propagating material for the basic or mother plantations of the Department of Agriculture and for the experimental glasshouses of the ARI.

(T. Kapari-Isaia, L.C. Papayiannis)

Grapevine pre-basic plantation



Efficient control of plant virus, virus-like and prokaryotic diseases starts with the use of healthy propagating material, which is free not only from disease symptoms, but also from latent infections. EU has recently imposed strict directives on distribution of grapevine material that involve phytosanitary testing of plants for several plant pathogens. Utilisation of healthy plant material seems nowadays the most promising tactic that can ensure good results to control these diseases. During the past decades, ARI has established a long-term project on the

maintenance of healthy propagative grapevine material under “pre-basic” status. Approximately 70 local or imported varieties are maintained under insect-proof net houses at Zygi experimental station. These plants are annually tested for a number of plant viruses including *Grapevine fan leaf virus*, *Grapevine fleck virus*, *Arabis mosaic virus* and *Grapevine leaf roll* associated viruses 1 and 3, viroids and several other prokaryotic pathogens. Tests are performed using pathogen-specific serological and molecular-based laboratory techniques. Virus-free grapevine plant cuttings are then given to the Department of Agriculture for further multiplication and distribution to Cypriot farmers. **(L.C. Papayiannis, T. Kapari-Isaia)**

Grapevine viruses

Grapevines are known to be infected with over 80 distinct virus species. A survey was conducted to investigate the presence of viruses in grapevine crops in Cyprus. More than 800 leaf samples from red and white varieties were randomly collected from the districts of Lemesos, Pafos and Lefkosia, and total RNA was extracted. All samples were tested using serological and molecular methods for the presence of 14 viruses involved in leaf-roll-associated and rugose woody disease complex, as well as fleck, infectious degeneration and decline disease complex. Results showed that among the viruses associated to leaf-roll disease, *Grapevine leafroll-associated virus 3* (GLRaV-3) was detected in more than 40% of the samples tested, followed by GLRaV-1 (6%) and GLRaV-2 (1%). The incidence of viruses involved in rugose woody complex was 14, 5 and 2% for *Grapevine virus A* (GVA), *Grapevine rupestris stem pitting-associate virus* (GRSPaV) and *Grapevine virus B* (GVB), respectively. *Grapevine fanleaf virus* (GFLV) and *Grapevine fleck virus* (GFkV) were also detected at 8 and 0.5% respectively. Two new viruses, *Grapevine roditis leaf discoloration associated virus* (GRLDaV) and *Grapevine pinot gris virus* (GPGV) were identified in a selection of samples from Greek and other imported varieties. Finally, *Arabis mosaic virus* (ArMV), *Tomato ringspot virus* (ToRSV), and the grapevine leaf-roll-associated viruses 4 and 7, were not detected. Interestingly, most viruses were detected in mixed infections of various combinations. The presence of these viruses has most likely resulted from the use of infected plant material combined with possible spread by vectors. (L.C. Papayiannis)

Epidemiological studies of whitefly-transmitted viruses in Cyprus

During the past twenty years, an extensive study has been conducted in order to assess the identity and prevalence of whitefly transmitted viruses and their vectors in major vegetable crops of Cyprus, using molecular-based diagnostic tools. Results showed that TYLCV (IS and MLD) is the only *Begomovirus* species involved in tomato yellow leaf curl disease epidemics and is widely distributed. TYLCV was also detected in 50 different weed species belonging to 15 botanical families, which could serve as natural virus reservoirs. Three *Crinivirus* species have been identified and associated with yellowing symptoms. In cucurbits, CYSDV is the predominant virus (95%) infecting cucumber, melon, watermelon and zucchini crops, followed by CCYV (20%), which has recently emerged and established as a new pathogen in Cyprus, and in most cases is detected in mixed infections with CYSDV. In tomato crops, ToCV is identified in plants showing chlorotic symptoms with a low incidence (2%). Finally, the ipomovirus CVYV is rarely detected in greenhouse cucumbers with symptoms of vein clearing (0.2%). In nature, all of these viruses are transmitted with *Bemisia tabaci* MEAM1 (also known as biotype B), which is currently the most abundant and important whitefly vector in Cyprus. This high incidence and distribution of whitefly-transmitted viruses in vegetable crops and weeds, requires the adoption of new management strategies that should focus on the use of resistant or tolerant hybrids when available, removal of alternative virus hosts and more effective control of whitefly vectors. (L.C. Papayiannis)



ENTOMOLOGY

Fruit fly pest prevention and management in the Balkans and the Eastern Mediterranean

In parts of the Balkans and the Eastern Mediterranean, the Mediterranean fruit fly (*Ceratitis capitata*) causes major damage to fruit production. Medfly reduces fruit production and increases insecticide use, and therefore exerts a direct impact on the production cost of agricultural commodities. Moreover, the recent introduction of exotic fruit fly species, such as the peach fruit fly, *Bactrocera zonata*, and the species of the oriental fruit fly complex *Bactrocera dorsalis*, in North Africa and the Middle East, poses a high threat to fruit and vegetable production of the Balkan and Eastern Mediterranean. To cope with the high risk of infestation from fruit flies, the International Atomic Energy Agency (IAEA) initiated a project with main objectives the knowledge-sharing among the countries of the region and the development and support of selected fruit fly suppression programmes. ARI is one of the institutions from 12 countries that participate in the project. **(N.A. Seraphides)**

Rearing of beneficial insect populations

Wide applications of chemicals to control insect pests generate many drawbacks concerning agriculture, environment and human health. By releasing natural enemies to control insect pests, the above drawbacks could be greatly reduced. For this purpose, populations of natural enemies of greenhouse pests, such as the parasitic wasp *Diglyphus isaea* against leafminers (*Liriomyza* sp.), the predatory bug *Macrolophus pygmaeus* against whiteflies, thrips etc., the lacewing *Chrysoperla carnea* against aphids, whiteflies etc., and the predatory bug *Nesidiocoris tenuis* against lepidopteran eggs, aphids etc., are reared at the main insectary of ARI. **(N.A. Seraphides)**

Management of the tomato borer *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae)

Tuta Absoluta is a devastating pest of tomato and other solanaceous crops. Following its introduction into Europe, North America and the Middle East, *T. absoluta* has already caused extensive economic damage to tomato production. In cooperation with the University of Cyprus, the intra and inter-specific interactions between two predators, *Nesidiocoris tenuis* and *Macrolophus pygmaeus* feeding on *T. absoluta* eggs were investigated. Results showed that *N. tenuis* is a more competitive predator species for *T. absoluta* eggs than *M. pygmaeus*, however, combination of the two predator species will lead to better pest suppression at high *T. absoluta* population densities. **(N.A. Seraphides)**

Susceptibility of the tomato borer *Tuta absoluta* to insecticides

Resistance of *Tuta Absoluta* to numerous insecticides has been reported, and it is mainly due to the fact that farmers do not follow a sustainable resistance management scheme. In order to develop a successful insecticide-resistance management strategy, nine Cypriot populations of *T. absoluta* were subjected to laboratory bioassays using four main insecticides applied by Cypriot farmers to control it. Results showed that the insecticides chlorantraniliprole and indoxacarb could not control the Cypriot *T. absoluta* anymore, while the insecticides emamectin benzoate and spinosad are still very effective. **(N.A. Seraphides)**

DNA barcoding identification of microlepidoptera species infesting *Juniperus foetidissima* berries

DNA sequences from an approximately 700 bp fragment of the COI gene were analysed from nine species collected from *J. foetidissima* berries in the Troodos forest area of Cyprus. Sequencing data were deposited in the NCBI GenBank database as the Accession Numbers of KY989993-KY989995 and MF001914-MF001919. DNA bold identification results of the four Lepidoptera samples revealed 99.5-99.83% similarity with *P. mariana*

species reported in Bulgaria (Bold sample IDs: BTLBP369-11 and BTLBP370-11). Interestingly, database analysis results of the other two processed samples (CYPAM19-MF001918 and CYPAM14- MF001919) showed 99% similarity proximity with *P. juniperana* species (Bold sample ID: FGMLH474-16) identified in Germany. Finally, the mtCOI sequence of three other Lepidoptera samples (LEP1CY- KY989993, LEP2CY- KY989994 and LEP3CY- KY989995) showed 99% homology with *Argyresthia aurulentella* reported in Bulgaria, Italy, Finland and UK (Bold sample IDs GMBUE3154-14, GMFIG616-12, LASTS819-15, CGUKD606-09, respectively). **(L.C. Papayiannis)**

NATURAL RESOURCES AND ENVIRONMENT

The research work of the Natural Resources and Environment (NRE) section concerned irrigation and fertilisation of crops, soil fertility, the use of treated waste water in agriculture, sustainable use of soil, water and energy, precision agriculture, biodiversity conservation and environmental issues in order to assist efforts for sustainable and viable agriculture under the impact of climatic change. An important part of the research work has been accomplished within the framework of competitive programmes from various funding agencies, such as the European Union, and the Research and Innovation Foundation of Cyprus.

PLANT NUTRITION AND SOILLESS CULTURE

Soilless culture (SC) is the most intensive production method in today's greenhouse industry, recognised globally for its ability to promote resource-efficiency and intensive plant production and, at the same time, to apply environmentally friendly technology. However, in Mediterranean countries, SCs have been performing below their potential. Particularly, irrigation and plant nutrition are the most important components, which enable farmers to control product yield and quality in the context of smart agriculture. Finally, in modern greenhouse horticulture, sustainable production mainly relies on hydroponic systems with reuse of drainage water, since a close control in the supply of water and nutrients is impossible in soil-grown crops.

Modelling Ca^{2+} accumulation in soilless zucchini crops: Physiological and agronomical responses

Existing empirical models capable of predicting salt (NaCl) accumulation in closed-loop irrigation systems were further extended to simulate Ca^{2+} concentrations in the root environment of zucchini crops. The mean uptake ratios of nutrients (i.e., N, P, K, Ca and Mg) and water denoted as uptake concentrations (UCs) were determined within a wide range of Ca^{2+} concentrations in the root zone, and may be used as a rough basis for the establishment of nutrient solution compositions for closed hydroponic Mediterranean zucchini crops. Photosynthesis, plant growth, yield and water uptake were restricted above a nutrient-induced EC value in the recycled solution of 3.2 dS m^{-1} related to osmotic potential effects (avg. 15% decrease up to 5.5 dS m^{-1}). However, water resources containing up to 3 mM Ca^{2+} can be safely used in closed hydroponic crops of zucchini (raised Ca^{2+} level up to 12 mM) in terms of growth, yield and quality of the produce. **(D. Neocleous)**



The effects of phosphorus supply limitation on photosynthesis, biomass production, nutritional quality, and mineral nutrition in lettuce grown in a recirculating nutrient solution

In this study, we investigated the impact of phosphorus (P) supply levels (0.8, 1.3 and 1.8 mM) in two green leaf lettuce (*Lactuca sativa* L.) types, namely 'Romaine' (cv. Nader), and 'Lollo' (cv. Bionda) grown in a recirculating nutrient solution. The biomass yield of the 'Romaine' type was reduced by 15% at the lowest P supply (0.8 mM), and plants showed reduced photosynthetic function (i.e. net photosynthesis, stomatal conductance, quantum yield and electron flow) and increased root/shoot ratio. On the other hand, the 'Lollo' type maintained photosynthetic rates and biomass accumulation in all cases and proved less sensitive to low P levels in the NS. In addition, lowering P supply boosted P-use efficiency (kg biomass kg⁻¹ P supply) in both types of lettuce. Nutrient to water uptake ratios of macro nutrients N, P, K, Ca and Mg were determined as follows: (i) 16.0, 1.3, 9.1, 3.1 and 0.9 mmol L⁻¹, respectively for 'Romaine', and (ii) 16.4, 1.3, 9.1, 3.3 and 0.9 mmol L⁻¹, respectively for 'Lollo'. The current experimental results suggest that, reducing the P supply to lower levels than those currently recommended for lettuce crops grown in closed hydroponics, considerably improves the P use efficiency in Mediterranean greenhouses without compromising yield. **(D. Neocleous)**



Seasonal variations of antioxidants and other agronomic features in soilless production of sweet peppers and fresh aromatic herbs

Our results indicate that in Mediterranean greenhouses during late autumn and winter light conditions (solar and ultraviolet radiation) can be insufficient to stimulate brightly coloured peppers with elevated content of antioxidants (e.g. phenolics, ascorbic acid and carotenoids). This suggests that a proper selection of greenhouse type and cover material in response to plant-light interception in conjugation with the selected crop and cultivation system may be a prerequisite to optimise environmental conditions for plant growth and elevated antioxidant phytochemicals in yearly-grown sweet coloured peppers in Mediterranean greenhouses. **(D. Neocleous)**. Furthermore, selected aromatic herbs of the Lamiaceae family, namely basil (*Ocimum basilicum*), mint (*Mentha viridis*), balm (*Melissa officinalis*) and thyme (*Thymus vulgaris*), were grown in Cyprus greenhouses under soilless conditions. Soilless greenhouse production of fresh aromatic herbs under Mediterranean climatic

conditions was proven to be efficient and perspective. Data suggest that balm and thyme is of superior quality in respect to antioxidant characteristics, while basil and mint would be mostly appreciated by growers in respect of fresh yield, water and nitrogen use efficiency. The growing season had also a marked influence on the antioxidant content of fresh herbal biomass. **(D. Neocleous)**



Other studies related to climate change, sustainable use of soil and water and precision agriculture, 2018-2019

Adjustment of irrigation schedules as a strategy to mitigate climate change impact on agriculture in Cyprus. **(P. Dalias, A. Christou, D. Neocleous)**

Achieving sustainable cultivation of vegetables. Developments in soilless/hydroponic cultivation of vegetables. **(D. Neocleous)**

Irrigation of greenhouse crops; Effects of cooling systems on greenhouse microclimate under Mediterranean climatic conditions; Dynamic assessment of whitewash shading and evaporative cooling on the greenhouse microclimate in a Mediterranean climate. **(D. Neocleous)**

European and National (RIF) Programmes, 2018-2019 Erasmus+ 2018

Competences development perspective IV. The participants were trained in hydroponics. The content of the programme is summarised as follows: Knowledge about hydroponics and its advantages, knowledge and experiences by technical visits to companies and seminars, alternative cultivating techniques emphasising in hydroponics, developing skills to optimise crop productivity. **(D. Neocleous)**

<https://ec.europa.eu/programmes/erasmus-plus/>

Interreg - MED Greenhouses

The programme's objective is to improve eco-innovation capacities of public and private actors in the greenhouse/agriculture sector through stronger transnational cooperation, knowledge transfer and better networks between research bodies, businesses, public authorities and civil societies. **(L. Vassiliou, D. Neocleous)**

<https://medgreenhouses.interreg-med.eu/>

Horizon IOF 2020 - IoT4Potato

An innovative, market-ready smart farming solution supports irrigation, pest management and fertilisation. Leveraging a network of telemetric IoT stations combined with satellite data and scientific models tailored to the specificities of the geographic areas, helps small-scale farmers to tackle those challenges. **(A. Stylianou, D. Neocleous)**

<https://www.iof2020.eu/>

Horizon IOF 2020 - CySloP

This use case delivers tailored information to farmers based on the data acquired by IoT devices (low-cost weather stations) regarding high farm input-costs (plant protection, irrigation water). As a result, IoT devices, cloud computing and analytics technologies translate data into services and increase the Total Farm Productivity (TFP) factor, which consequently assures food security **(G. Adamides, D. Neocleous)**

<https://www.iof2020.eu/>

RIF / RESTART 2016-2020 - MAGNET

The aim of the action is to provide the basis of a new approach of soil and water resource management in Cyprus that is related to farming, as a means of adaptation to climate change. The novelty of the proposed approach of crop fertilisation and irrigation is that it allows farmers, through geographic information systems (G.I.S.) that combine different layers of information, to retrieve and manage data in a more useful manner. **(M. Omirou, D. Neocleous)**

INTEGRATED WATER RESOURCE MANAGEMENT AND IRRIGATION

Research on integrated water resource management is currently devoted mainly to wastewater reuse in agriculture. Field experiments are performed for appraising the effects of wastewater reuse for irrigation purposes on the environment and on public health. In addition, field and hydroponic experiments are carried out in order to evaluate xenobiotic compounds (pharmaceuticals) uptake by plants.

Pharmaceutically active compounds released in agroecosystems can be considered as emerging plant stressors

Pharmaceutically active compounds (PhACs) entering agroecosystems as a result of various human activities may be taken up by and accumulated within crop plants, with potential human health implications. Despite their extensive metabolism by a sophisticated enzyme-based detoxification system in plant cells, PhACs and their transformation products (TPs) may result in adverse effects on plants' physiology. PhACs-mediated phytotoxic effects, as well as plants' defense responses have been depicted on plants exposed to individual or low number of PhACs under controlled conditions. Cocktails effects and synergistic interactions of the mixtures of PhACs in actual agroecosystems towards phytotoxicity should be taken into consideration. Considering PhACs as emerging plant stressors will better facilitate the understanding of their phytotoxic effects. **(A. Christou)**

Uptake and bioaccumulation of three widely prescribed pharmaceutically active compounds in tomato fruits and mediated effects on fruit quality attributes

This study aimed at evaluating: 1) the uptake and bioaccumulation of three common PhACs (diclofenac, DCF; sulfamethoxazole, SMX; trimethoprim, TMP), either applied individually ($10 \mu\text{g L}^{-1}$) or as mixture ($10 \mu\text{g L}^{-1}$ each) in tomato fruits, and 2) the PhACs-mediated effects on fruit quality attributes. DCF was not detected in tomato fruits, whereas both SMX and TMP were detected in varying concentrations in fruits, depending on the time of harvest, the mode of application and the allocation of plants in the greenhouse. Important fruit quality attributes, such as soluble solids and carbohydrate (fructose, glucose, sucrose, total sugars) content were significantly impacted by all studied PhACs applied individually. In addition, no additive or synergistic effects of the mixture of PhACs on studied fruit quality attributes were revealed. Gene expression analysis showed that the impacts on the carbohydrate content of fruits can be attributed to the significant modulation of the abundance of transcripts related to the biosynthesis and catabolism of sucrose, such as SISuSys, SILin5 and SILin7. **(A. Christou)**

Ranking of crop plants according to their potential to uptake and accumulate contaminants of emerging concern

Contaminants of emerging concern (CECs) are routinely detected in TWW-irrigated agricultural soils and runoff from such sites, in biosolids- and manure-amended soils, and in surface and groundwater systems and sediments receiving TWW. Crop plants grown in such contaminated agricultural environments have been found to uptake and accumulate CECs in their tissues, constituting possible vectors of introducing CECs into the food chain; an issue that is presently considered of high priority, thus needing intensive investigation. Both biotic (e.g. plants' genotype and physiological state, and soil fauna) and abiotic factors (e.g. soil pore water chemistry, physico-chemical properties of CECs and environmental perturbations) have been proven to influence the ability of crop plants to uptake and accumulate CECs. According to authors' estimates, based on the thorough elaboration of knowledge produced by existing relevant studies, the ability of crop plants to uptake and accumulate CECs decrease in the order of leafy vegetables > root vegetables > cereals and fodder crops > fruit vegetables; though, the uptake of CECs by important crop plants, such as fruit trees, is not yet evaluated. **(A. Christou)**



Adjustment of irrigation schedules as a strategy to mitigate climate change impacts on agriculture in Cyprus

This study explored the seasonal or monthly changes in crop evapotranspiration (ET_c) and net irrigation requirements (NIR) of a number of permanent and annual crops over two consecutive overlapping periods (1976–2000 and 1990–2014). While the differences in the seasonal ET_c and NIR estimates were not statistically significant between the studied periods, differences were identified via a month-by-month comparison. In March, the water demands of crops appeared to be significantly greater during the recent past in relation to 1976–2000, while for NIR, March showed statistically significant increases, and September showed significant decreases. Consequently, the adjustment of irrigation schedules to climate change by farmers should not rely on annual trends as an eventual mismatch of monthly crop water needs with irrigation water supply might affect the critical growth stages of crops with a disproportionately greater negative impact on yields and quality. The clear increase in irrigation needs in March coincides with the most sensitive growth stage of irrigated potato crops in Cyprus. Therefore, the results may serve as a useful tool for current and future adaptation measures. (P. Dalias, A. Christou, D. Neocleous)

SOIL FERTILITY IMPROVEMENT

Digital maps could become tools of adaptation and mitigation to climate change and support many environmental applications because they have important qualities. They can be easily updated, they require digital space for storage, which is practically unlimited, they do not have the same scale limitations as paper maps, they allow filtering for specific features, they can be linked with simulation models or calculation spreadsheets and they are dynamic.

Soil fertility mapping

In 2019, a new internal (ARI) project has been initiated aiming at the production of soil fertility maps, illustrating the geographic variation of soil physical and chemical properties or indices (e.g. pH, EC, organic C available P, available K). It is being carried out in coordination with the external (RIF, restart 2016–2020) project “MAGNET”,

which targets the establishment of a modern national infrastructure, capable of collecting and storing soil microorganisms and soil microbial genetic material. One of the main intended applications of soil fertility mapping is the improvement of fertilisation schedules. Excessive use of fertilisers may decrease yields, but it certainly increases production costs and greenhouse gas emissions and pollutes waters. Optimisation of fertiliser inputs in the field needs to balance needs of crops with available quantities of nutrients in soils (assessed with soil analysis) and amount of fertiliser added (determined based on the interpretation of soil analysis). **(P. Dalias, D. Neocleous)**

AGRICULTURAL AND ENVIRONMENTAL ENGINEERING

Application of renewable energy sources in agriculture

Greenhouse horticulture and floriculture heavily depends on some form of energy source, since heating during winter is absolutely necessary to maintain production. Heating, however, contributes to a considerable increase in production costs. A study is carried out regarding the heating requirements of greenhouses in different locations in Cyprus and the corresponding CO₂ emissions resulting from burning different kinds of fuels. Alternative energy sources, such as solar, shallow geothermal and biomass energy are also being considered. Additionally, the improvement of the efficiency of Photobioreactors is investigated for the cultivation of microalgae to be used as potential energy sources and production of nutrient products. The study on the use of solar energy for the drying of agricultural products was continued, by improving the design of Solar Driers. **(P. Polycarpou)**

FLORICULTURE/ NATIVE PLANTS

Research activity focused on the evaluation of crop production systems and practices of ornamentals in the open field and/or greenhouses, covering all stages of flower production. More recently, the research activities have been focused on the evaluation of species from the Cyprus flora for potential use in commercial floriculture and landscape. New collaborations and participation in European and other external funded projects were reinforced.

Evaluation of endemic and native species of the Cyprus flora for potential use in commercial floriculture and landscaping

Cyprus due to the special climatic conditions has developed a rich and unique flora with high percentage of endemism that accounts to 8.6%. These species are ideal for use in commercial floriculture as pot plants and in landscaping due to the fact that they are well adapted to the climatic conditions of Cyprus and possibly require a decreased amount of inputs when under cultivation. The aim of the project is the creation of a collection of different species from the Cyprus flora that have a potential use in commercial floriculture. Specifically, research activities concern the collection of the material from the wild and the development of propagation protocols. Subsequently, their growth and development is studied and evaluated to create cultivation protocols and define possible uses. For example, plants of *Euphorbia veneris* were collected, propagated and evaluated for their use in green-roof establishments. **(L. Vassiliou)**

European and National (RIF) Programmes, 2018-2019

Interreg - MED Greenhouses

The *Interreg MED Project "MED Greenhouses"*: "Green Growth through the capitalisation of innovative Greenhouses" started in February 2018 and finished in December 2019. The University of Thessaly in Greece was the lead partner and ARI was the partner for Cyprus. The project was co-financed by the European Regional Development Fund, and it additionally involved partners from the Region of Thessaly, Spain, France, Italy and Albania. The overall objective was to improve eco-innovation capacities of public and private actors in the greenhouse/agriculture sector through stronger transnational cooperation, knowledge transfer and better networks between research bodies, businesses, public authorities and civil societies. (L. Vassiliou, D. Neocleous)
<https://medgreenhouses.interreg-med.eu/>

Erasmus+ 2019 - "GreenNet"

The *Assistant Gardener Curriculum for people with Intellectual Disabilities - GreenNet* project aims at improving and innovating the inclusion of people with intellectual disabilities through fostering specific actions within the framework of Adult Education and Rehabilitation for people with intellectual disability (PIDs). (L. Vassiliou, C. Stavridou)
<http://greenet.omegatech.gr/>

COST Action CA18201 "ConservePlants"

The main aim of the *COST Action "An integrated approach to conservation of threatened plants for the 21st Century"* is to improve plant conservation in Europe through the establishment of a network of scientists and other stakeholders who deal with different aspects of plant conservation from plant taxonomy, ecology, conservation genetics, conservation physiology and reproductive biology to protected area's managers, not forgetting social scientists, who are crucial when dealing with the general public. (L. Vassiliou)
<https://www.cost.eu/actions/CA18201/#tabs|Name:overview>

RIF / RESTART 2016-2020 – SPACES

The general objective of the project is to develop the technology that can monitor soil parameters. That technology is the missing link between the classical approach of providing water and fertilisers to plants at certain amounts without knowing the actual state of the soil, and precision agriculture of providing exactly what is required by monitoring the state of the soil, a technique featuring to be the approach of the future. (L. Vassiliou)



SUSTAINABLE ENVIRONMENT AND PROTECTION FOR WILDLIFE

Mushroom taxonomy

The mycenas are a group of delicate and dainty mushrooms, which until now have been poorly known in Cyprus. This study presents the results of a survey of the Mycenas of Cyprus, describing the first eight species collected: *Mycena amicta*, *M. haematopus*, *M. sanguinolenta*, *M. seynii*, *M. pseudocorticola*, *M. epipterygia*, and *M. pura*. The collection of mushrooms for eating in Cyprus is a popular pastime. Coupled with the excitement of picking mushrooms in the wild is the risk of handling poisonous varieties. The purpose of this project is to provide easy-to-follow guidelines on how to differentiate edible from other look-alike poisonous species to avoid mushroom poisoning among mushroom pickers. (E. Hadjisterkotis)

The study of the rodents of Cyprus

The presence of *R. rattus* in Cyprus has long been established, while that of *R. norvegicus* is still debated. In this study, the first body and cranial measurements as well as molecular typing of *R. norvegicus* specimens were provided. The analysis of mtDNA D-loop sequence confirmed that the analysed samples were *R. norvegicus* and pointed out the occurrence in Cyprus of at least two maternal lineages of this species. Rats are the most damaging alien predators to have been introduced to Cyprus, having a negative effect on island biota and causing huge damages to agriculture. A natural enemy of rats is the barn owl (*Tyto alba*). Barn owls are species with a restricted habitat, limited by the presence of suitable natural cavities/holes for nesting. In cooperation with the University of Cyprus, under the project 'Black Gold': Revival of the cultivation of Carob tree in Cyprus' a new more efficient design of nesting box for barn owls was installed.



Rattus norvegicus



Rattus rattus



Barn owls *Tyto alba* in their nesting box



Nesting boxes designed by the ARI ready for instalment of *Tyto alba*

Spiny mice of the *Acomys cahirinus* group display a complex geographic structure in the Eastern Mediterranean area. In order to better elucidate the evolutionary relationships of insular populations from Crete and Cyprus with the continental ones from North Africa and Cilicia in Turkey, genetic and morphometric variations were investigated, based on mitochondrial D-loop sequences, and size and shape of the first upper molar. Due to its isolated distribution and morphological characteristics, the Cyprian spiny mouse *Acomys cahirinus nesiotus* was characterised and maintained as separate subspecific evolutionary unit.

The complexity of house mouse (*Mus musculus domesticus*) population genetics and its value as a bioproxy for studying modern human movement was investigated. The analysis was performed using 221 new mitochondrial D-loop sequences and assessed the fine-scale population genetic structure using 18 autosomal microsatellite loci from 191 modern house mice specimens. Two main waves of mouse introductions were tentatively identified based on coalescent and mismatch analysis. The first is apparently related to the Bronze Age expansion and the second one to more recent human movements. (E. Hadjisterkotis)

The vultures (*Gyps fulvus*) of Sardinia, Crete and Cyprus

The islands of Sardinia, Crete and Cyprus are hosting the last native insular griffon populations in the Mediterranean basin. The study of D-loop region sequence was carried out on the vultures of the above islands to estimate the genetic diversity and phylogenetic relationship within and among these three populations. Strong genetic variability was observed, which is influenced by isolation leading to the appearance of island variants. This research lays the foundation for griffon vulture conservation and restocking programmes. (E. Hadjisterkotis)

Identification of an ancestral haplotype in the mitochondrial phylogeny of the ovine haplogroup B

Following the first complete sequence of Cypriot mouflon (*Ovis gmelini ophion*) mtDNA and phylogenetic analyses using a large dataset of whole *Ovis* mitogenomes, the first complete mtDNA sequence of the long-time isolated Sardinian mouflon (*Ovis gmelini musimon*) was performed. Applying Bayesian inference, we identified an early split (110,000 years ago) of the Sardinian mouflon haplotype from both sheep and mainland European mouflon belonging to haplogroup B, the latter two sharing a more recent common ancestor (80,000 years ago). The results suggest the Sardinian mouflon haplotype as the most ancestral in the HPG-B lineage, hence partially redrawing the known phylogeny of the genus *Ovis*. (E. Hadjisterkotis)



Cyprian mouflon

RURAL DEVELOPMENT

The Rural Development Section of the Agricultural Research Institute conducts research aiming towards the sustainable development of the agricultural sector in Cyprus and the improvement of the quality of life of Cypriot farmers. The activities of the Section encompass topics related to agricultural economics, marketing and trade, as well as work on smart agriculture (or smart farming, which includes research on applications of Information and Communication Technologies, Remote Sensing, Internet of Things (IoT) and Robotics in agriculture. The Section collaborates with the Ministry of Agriculture, Rural Development and Environment and undertakes targeted studies and technical reports on agricultural economics, trade and policy, supporting decision-making. Finally, the Section is also actively involved in EU funded projects.

AGRICULTURAL ECONOMICS

Investigating the sustainability of the Agricultural Production System in Cyprus

The ultimate goal of this research project is to examine, for the first time, the environmental, social and economic sustainability of divergent farming systems (FSs) in Cyprus, using as case studies two key agricultural districts, viz. Larnaka and Ammochostos. To achieve this goal, quantitative and qualitative research methods (multi-strategy design) are integrated in order to increase the reliability of the results. The main qualitative outputs were presented in the 2014-2015 biennial review. The objective of the quantitative research is twofold: (a) to identify and characterise the major FSs prevailing in the study area; and (b) to assess their sustainability performance on the basis of the traditional triad: environmental, social and economic sustainability. Within the context of the quantitative approach, a representative sample of 354 farmers was determined using proportionate stratified random sampling method. To obtain the primary data, a well-structured questionnaire was developed, including closed and open-ended questions. The questionnaire was completed through ca. 90-minute face-to-face interviews with farmers, and 324 fully-completed questionnaires were finally collected. To identify the diverse FSs in the study area, Principal Component Analysis and Cluster Analysis (Hierarchical and k-means) were applied in tandem via a six-step methodological procedure. The process led to the identification of six significantly different FSs (FS1-FS6) differentiated by land use, livestock, production orientation, farm, household, labour and economic variables (**Table 7**). FS1-FS4 were crop-oriented and FS5-FS6 were livestock-oriented, cultivating cereals/fodder crops for livestock feeding. Only FS1 was profitable without subsidies, which were negatively correlated with economic outputs. This brings into question the effectiveness of subsidies in providing the basis for a more profitable agricultural sector. FS3-FS5 households sought off/no-farm income mainly for their survival, but not to cross-subsidise the farm. Small crop-oriented farms (FS4) and medium-sized livestock-oriented farms (FS5) had several weaknesses, such as elderly, low-educated farmers and low profitability; therefore, their viability should be the priority of decision makers. Weak complementarity was also observed between the main system components (crop, livestock, off/non-farm income), which might negatively affect sustainable intensification. The importance of participation in producer groups/organisations for farm sustainability was also underlined. The overall results can be used for a more focused agricultural policy, tailored to the different constraints and opportunities of FSs, but also to inform public decision makers who are responsible to design and implement agricultural policy in Cyprus. The next step of the project is to assess and compare the sustainability performance of the identified FSs using an integrated indicator-based sustainability assessment framework developed by the research team. (**A. Stylianou**)

Table 7. Identified farming systems and their distribution across the study districts

Label of farming systems (n = number of farms)	Acronym	Share in the total sample (%)	Distribution of farming systems across the study districts (% of farms)	
			Larnaka	Ammochostos
Medium-sized irrigated farms with open field vegetables/potatoes, profitable with or without subsidies (n = 60)	FS1	18.5	36.7	63.3
Small to medium-sized irrigated farms with greenhouse/open field vegetables and permanent crops, labour-intensive (n = 46)	FS2	14.2	65.2	34.8
Large farms with market-oriented rain-fed cereals and fodder crops ^a , high dependency on subsidies and high off/non-farm income (n = 35)	FS3	10.8	85.7	14.3
Small irrigated farms with open field vegetables, potatoes and permanent crops, off-farm based (n = 70)	FS4	21.6	41.4	58.6
Specialised medium-sized sheep/goats farms with high off/non-farm income (n = 103)	FS5	31.8	77.7	22.3
Large specialised, capital-intensive dairy cattle farms, with young and educated farm managers (n = 10)	FS6	3.1	80.0	20.0

^a Cereals and fodder crop production is destined for the market and not for on-farm consumption, viz. not for livestock feeding.

Identifying Business-to-Business Unfair Trading Practices in the food supply chain of Cyprus

Unfair Trading Practices (UTPs) between businesses in the food supply chain have a significant impact on the various stakeholders involved, and on the environment. So far, no attempt has been made at the Member State level for the identification of UTPs in the food supply chain and of their impact on the relevant stakeholders. This study drew on this gap and attempted to identify the UTPs that exist in the Cypriot food supply chain, assess their impact on the involved stakeholders and provide guidelines that will assist the transposition of EU relevant Directive to the national law. To achieve this goal, the study was based on a quantitative survey of a representative sample of businesses using a specific questionnaire. The results showed that particular UTPs do appear in the food supply chain with variable frequency, while the majority of businesses have been victims of UTPs in the last five years. Notably, the estimated cost of UTPs as a percentage of the business annual turnover

is considered important ranging from 5.7% for retailers to 31.9% for farmers (**Table 8**). Thus, most participants agree that UTPs in the agricultural food sector should be regulated by national legislation. We argue that the national legislation for UTPs should be a mix of policies that integrate private, administrative and judicial methods of monitoring and enforcement. Policy and decision makers should seek to reinforce the role and the bargaining power of small businesses in the food supply chain. This might be accomplished through the development of efficient producer organisations, short food supply chains, inter-branch organisations and strategic partnerships. (**M. Markou, A. Stylianou, M. Giannakopoulou, G. Adamides, G. Papadavid**)

Table 8. Selected characteristics of the stakeholders and estimated UTP cost as a percentage of the annual turnover in the food sector, by occupational category and in the overall sample

Characteristic /variable (unit)	Occupational category						
	Crop /livestock farmer (n=52)	Fisherman / fish farmer (n=42)	Producer Organisa tion (n=13)	Processor (n=33)	Whole saler (n=43)	Retailer (n=40)	Overall sample (n=199)
Number of employees	2.9 (2.0)	11.1 (2.0)	8.7 (5.0)	30.5 (8.0)	13.4 (7.0)	12.6 (7.5)	10.3 (3.0)
Annual turnover (k€)	54.07 (15.35)	1,346.43 (20.00)	3,501.75 (3,000.00)	5,735.64 (600.00)	2,713. 10 (800.0 0)	1,880.92 (500.00)	1,878.40 (85.00)
Exports as a percentage of annual turnover (%)	2.7 (0.0)	4.6 (0.0)	14.5 (0.0)	18.4 (5.0)	2.7 (0.0)	0.3 (0.0)	5.4 (0.0)
Estimated UTP cost as a percentage of annual turnover (%)	31.9 (30.0)	11.6 (10.0)	14.1 (10.0)	10.6 (5.0)	11.6 (10.0)	5.7 (1.8)	16.6 (10.0)
<i>Stakeholder category (%)</i>							
Buyer	0.0	0.0	0.0	0.0	0.0	65.0	13.1
Supplier	90.4	95.2	38.5	9.1	4.7	5.0	46.7
Supplier and buyer	9.6	4.8	61.5	90.9	95.3	30.0	40.2
<i>Food group (%)</i>							
Crop production	69.2	0.0	92.3	48.5	69.8	70.0	57.8
Livestock production	30.8	0.0	7.7	39.4	7.0	10.0	17.1
Fishery/aquac ulture products	0.0	100.0	0.0	12.1	23.3	20.0	25.1

Values in the table present the average of the numerical (quantitative) variables, as well as the relative frequency (%) for the categorical variables. In parenthesis next to the average is the median; n is the size of the sample, which for some variables is smaller than the indicated size due to missing values.

Perceptions of Cypriot consumers towards the traceability of food products

In the framework of the research programme **Rural Development and Marketing of Agricultural Products**, a new project titled “Perceptions of Cypriot consumers towards the traceability of food products” is underway. The ultimate goal of this project is to examine the perceptions of Cypriot consumers towards the traceability of food products. Specifically, this research aims to study the degree of importance that consumers attribute to traceability information (i.e. what is indicated on the packaging / label) when purchasing their food products. For the purposes of this study, the products are limited to fresh agricultural products. Consumers will be segmented based on selected features related to the traceability of food products, and a comparison will be made on different consumer segments regarding their perceptions, preferences and needs towards the traceability of food products, but also based on specific exogenous characteristics (e.g. gender, age, educational level), which are expected to affect their perceptions. In addition, the factors that affect consumers’ perceptions towards the traceability of food products will be investigated. **(M. Giannakopoulou, S. Ioannou, G. Adamides, A. Stylianou, M. Markou)**

EU FUNDED PROJECTS

Digital Ecosystem Utilisation (<https://www.iof2020.eu/trials/vegetables/digital-ecosystem-utilisation> CYSLOP) is a sub-grantee open call project pilot study within the H2020 project “Internet of Food and Farm - IoF2020” (<https://www.iof2020.eu>), that aims to deliver tailored services to farm operators based on IoT data acquired on-field. By utilising data stemming from IoT devices in the field, cloud computing and analytics technologies, this use case timely notifies the farmer to proceed with such activities. The result from synergised parameters such as air humidity, temperature and other weather conditions is a service that increases the total



CYSLOP sensor installation inside a strawberry tunnel

farm productivity, contributing to food security for an increasingly populated world. Furthermore, information tailored to farmers’ individual needs lowers their resource costs through early warnings regarding crucial factors in irrigation. By incorporating innovative traceability technology, this use case is among the first to integrate information from the entire food value chain (from farm to shelf) to a marketplace, offering elaborate value propositions to users. Hence, it significantly improves consumers’ perception of food safety while enabling stakeholders in the agri-food sector to participate in an innovative digital ecosystem. Moreover, traceability technology will be integrated with the support of relevant experts (5.3 IoF2020 use case) so that IoT data and post-farm critical events are coherently grouped. Ultimately, consumers will enjoy a complete data story-telling regarding the origins, conditions and steps of the agrifood product and have the opportunity to further interact with the producer. In July 2019, the first three (3) farms in Cyprus were equipped with IoT sensor devices. The Agricultural Research Institute had arranged the

practicalities of FINT's visit and organised the visits at the three locations. Fruit farms with strawberries, berries and hydroponic tomato were equipped with soil and air sensors. The deployment team re-visited Cyprus in November 2019 to install newly designed FINoT irrigation controllers aiming to maximise water efficiency during irrigation and increase the field's performance (**G. Adamides, A. Stylianou, D. Neocleous, M. Giannakopoulou, V. Vassiliou**)

The project “**Data-driven potato production – IoT4Potato**” (<https://www.iof2020.eu/trials/arable/data-driven-potato-farming>) is funded by the large-scale H2020 project “Internet of Food and Farm - IoF2020” (<https://www.iof2020.eu>). The IoT4Potato aims at building on top of gaisense, an innovative market-ready IoT-based Smart Farming solution, and extend it to enable the development of services for irrigation, pest management and fertilisation for potato producers in Cyprus, Poland and Ukraine. The services, which aim at reducing the costs of potato production per hectare of cultivation while improving its quality, will use scientific models tailored to the specificities of the targeted areas, the different potato varieties and the specific requirements of the targeted markets. The models will be fed with data from a network of telemetric IoT stations (Gaiatrons) installed in the field, collecting atmospheric and soil measurements, satellite data (Sentinel 1 and 2), as well as data provided by the producers and agronomists involved, including information related to inputs/outputs, but also to all those parameters whose values identify the specificity of each production unit in the vast variety of cases. These services will be used by the agronomists and farming advisors consulting the involved producers, which will feed the provided applications with their own observations, and produce the specialised advice (on a case-by-case basis) in a form accessible and understandable by each producer. For Cyprus, two potato fields located in the Kokkinochoria area will be used as case studies. (**A. Stylianou, G. Adamides, D. Neocleous, M. Giannakopoulou, V. Vassiliou**)

The **ERASMUS+ project** titled “Enhancing Youth Entrepreneurship Skills, Careers Guidance and Competences in Agriculture Through a Game-based Virtual Reality Platform” (AGRIENT- [http:// www.agrient.eu](http://www.agrient.eu)), aims at producing an innovative educational platform and providing a systematic approach to train and support young people to run successfully their own agribusinesses. Several innovative open courses and training procedures will be designed to efficiently teach entrepreneurship, focused on the agriculture domain. The educational platform will utilise and use advanced ICT-based educational methods like 3D virtual reality. This will contribute in ICT-based innovative teaching and training as well as assessment. Teachers will be offered new and more attractive ways of teaching, through the 3D Virtual reality educational environment that will be developed. Learners will have the opportunity to learn more efficiently and improve their skills on agriculture and entrepreneurship by using advanced ICT technologies (like virtual reality), thus improving the overall quality of learning. The design and formulation of advanced 3D Virtual Reality educational procedures can offer new, more efficient ways of teaching, suitable for the Agro-Entrepreneurship domain, and also assist young people in getting valuable knowledge that will allow them to put their own ideas into practice and have successful businesses in the agricultural domain. (**G. Adamides, M. Giannakopoulou, S. Ioannou, A. Stylianou**)

SWSOIP Project: ‘Smart Watering System for Optimising Irrigation Process’ aims to provide ‘new’ irrigation data based on the indirect estimation of evapotranspiration using both satellite and meteorological inputs. This data can be used to inform the producers and the decision-makers for the water demand of their crops aiming to better and more rational management of irrigation water. The ‘Smart Watering System’ will automatically estimate the water demand for irrigation purposes and will release automatically the optimum water quantity for each crop-type through the ‘Smart CropWATER Valve’ without any human intervention. SWSOIP platform consists of the frontend and backend system. The SWSOIP frontend aims to communicate with the farmers in order to collect inputs related to the farmers and their crops such as farmers’ id; crop type; cultivation date; plot area etc. and provide outputs to the farmers related to the water needs of their crops. The SWSOIP backend aims to gather and process all the data such as satellite; meteorological and *in-situ* (spectroradiometric; LAI; CH)

based on the inputs of the farmers. Then the backend system will be able to estimate the irrigation demand for each farmer and plot and will communicate this output both with the frontend system to inform the farmer and the WISENSE Platform, which will transfer this information to the CropWATER Valve to provide automatically the estimated water quantity to the crops without any human intervention. The proposed product is expected to contribute and have an effective impact on water saving and smart management of water resources since lack of water is one of the most serious problems that Cyprus has been facing for centuries, and agriculture accounts for about 69% of the total water consumption. **(G. Papadavid, G. Adamides)**

RESOURCE project: BalkanMed (INTERREG). The project reflects the jointly identified need to strengthen the collaboration between the competent authorities and institutions of the participating countries, capitalising on experiences and results achieved in past projects, with the aim to improve their existing institutional capacity in terms of natural resource management and related legal framework implementation. This common need was identified by the iBEC (LP) which addressed the Ministry of Rural Development & Food of Greece (Observer partner) and the Ministry of Environment of Albania (PP5) and jointly initiated a consultation procedure among stakeholders of the Balkan-Med area. The process resulted in the development of the present partnership that includes the involvement of Ministries from four (4) participating countries. Partners jointly shaped the specific project idea and contributed to the project's detailed design through meetings and efforts that took place since the beginning of January 2016. These efforts resulted in creating communication channels and in developing this Project Proposal through joint coordinated efforts. The Re-Source project tackles the need for improved transnational governance capacity in relation to the following three fields: 1) irrigational water management, 2) codes of good agricultural practices (CGAP), and 3) soil erosion risk assessment. The proposed project aims to capitalise on results from previous, namely digital tools produced within the "Digital Convergence" framework and the "AGRO-LESS" project (ETCP Greece-Bulgaria 2007-2013) and expand its use within the Balkan territory into five (5) Balkan-Med countries (Greece, Bulgaria, Albania, North Macedonia and Cyprus) in order to promote governance capacity and legal framework implementation in all three aforementioned fields. The project will be based on the system of digital services already established within iBEC (through the two projects mentioned above), and will further develop, with an emphasis on the following three services: 1) application of precise irrigation: a digital model for the application of precise irrigation in space and time will be further upgraded, customised and applied within the Greek and Albanian territories; 2) application of codes of good agricultural practices: a digital tool for the evaluation of the implementation of the CGAP (a set of more efficient, environmentally friendly practices in agriculture on a national and European basis) will be customised and applied within the Cyprus and North Macedonia territories; 3) application of soil erosion risk assessment: a digital model for the large-scale risk assessment of soil erosion will be customised for use within the Bulgarian territory. **(G. Papadavid, G. Adamides, A. Stylianou)**

The **LIFE+ project** titled "Adaptation to climate change impacts on the Mediterranean islands' agriculture" (ADAPT2CLIMA) aimed to increase knowledge on the vulnerability of EU Mediterranean agriculture to climate change and to support decision making for adaptation planning in Crete (Greece), Sicily (Italy) and Cyprus (<http://adapt2clima.eu/en>). A set of climatic, hydrological and crop simulation models for the assessment of climate change impacts on agriculture were deployed, and a decision support tool for the elaboration of adaptation strategies for the agricultural sector was created (<https://tool.adapt2clima.eu/>). In the frame of the project, the National Adaptation Strategy of Cyprus Agriculture to Climate Change was developed. The strategy contains a summary of future changes in climate conditions and their impacts on crops and water resources, a strategy for efficient water use in agriculture and implementation and a monitoring plan with specific indicators. It complements the National Strategy on Climate Change and enables policy makers to integrate adaptation measures in the forthcoming Rural Development Programming Period 2021-2027 and the Climate Change Action plan. **(M. Markou, A. Stylianou, G. Papadavid)**

The **LIFE+ project** titled “Revamping organic farming and its products in the context of climate change mitigation strategies” (ORGANIKO) aims to demonstrate the comparative advantages of organic versus conventional farming and products using indicators of mitigation efficiency to climate change, agronomic and environmental quality, and decreased children exposures to pesticides, promoting healthy food for better children’s health. The project is coordinated by the Cyprus University of Technology, whereas the Agricultural Research Institute, the Department of Environment and the Kyoto Club are project partners. The project deliverable “Stakeholder Organic Sector Mapping in Cyprus” was compiled by A. Stylianou. The report was included in the preparatory actions of the project and aimed at providing a comprehensive mapping of the organic sector in Cyprus from the production at farm level right through to processing and trading. Hence, it described the current situation of the wider organic food supply chain in Cyprus and provided useful information for each actor constituting the supply chain. In addition, A. Stylianou contributed to the writing of deliverable “ORGANIC FARMING AND CLIMATE CHANGE: Literature Review Synthesis and Perspectives”, to the development, data curation and analysis of two questionnaires administered to organic farmers, as well as to various seminars that took place around Cyprus for dissemination purposes (**M. Omirou, D. Neocleous, P. Dalias, D. Fasoula, A. Stylianou, S. Ioannidou, I.M. Ioannides**)

PROJECTS FUNDED BY THE RESEARCH & INNOVATION FOUNDATION

The project “Proactive Producer and Processor Networks for Troodos Mountains Agriculture – 3PRO-TROODOS” is funded by the RIF of Cyprus and coordinated by the Cyprus Institute. The goal of the **3PRO-TROODOS** project is to improve agricultural production and food processing in the Troodos Mountains of Cyprus, through social innovation, sustainable natural resource management and climate change adaptation. The project aims (a) to develop a voluntary Troodos quality certification label through a fully participatory process; (b) to improve processing through innovation and linkages between producers and processors; (c) to quantify current and future irrigation water demands based on high-resolution climate projections (2020–2050); (d) to develop guidelines for sustainable irrigation; (e) to test four climate resilient innovations with pilot farmer groups; and (f) to analyse the costs and benefits of tested innovations and the socio-economic impacts of the quality certification label through input-output modelling. Through the integration of people, scientific and practical knowledge and experiences, the project consortium can add value to farming, make agriculture climate resilient and sustain the beautiful cultural landscapes of the Troodos Mountains. The role of ARI in the project implementation is of vital importance, since it is highly involved in all Work Packages (WP), but chiefly in WP3 and WP6. (**A. Stylianou, G. Adamides, S. Ioannidou, C. Stavridou, D. Fasoula**)

DISSEMINATION ACTIVITIES

The Section is responsible for maintaining the ARI website and various social media network services. ARI publications since 1965 have been digitized, and full-text articles are available from the Institute’s website <http://www.ari.gov.cy>. The Rural Development Section makes use of several social networking tools such as Facebook, <https://www.facebook.com/ARICyprus>, and Twitter http://www.twitter.com/ari_rd. These services are used to share information about several topics related to ARI activities. (**G. Adamides**)

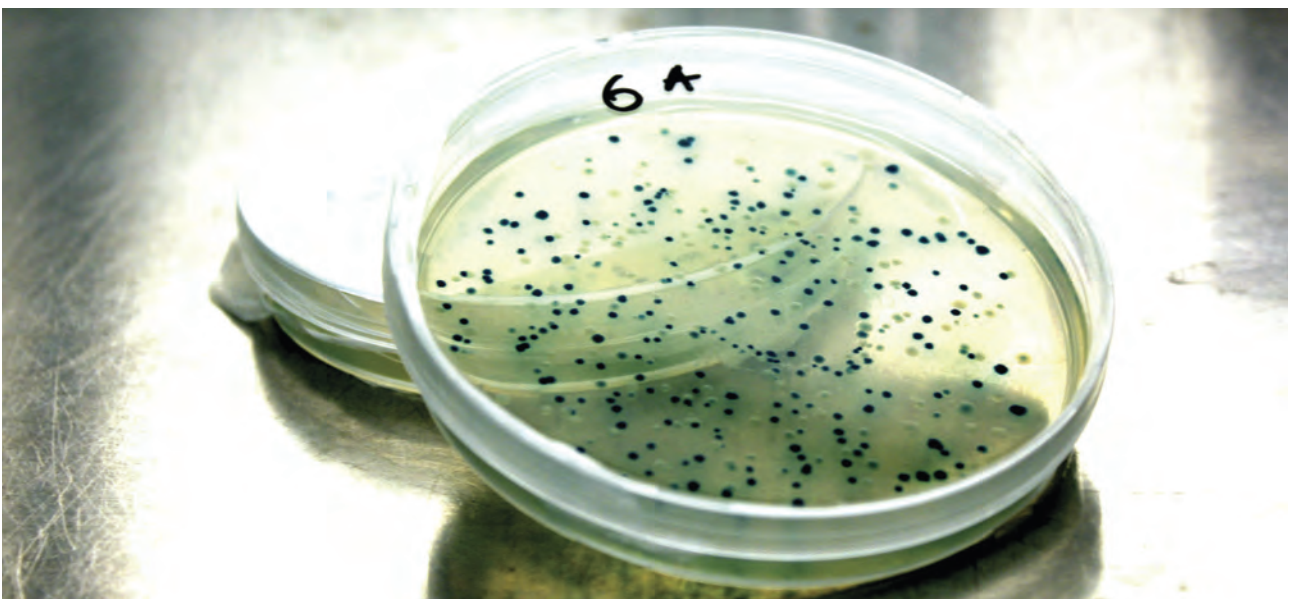
AGROBIOTECHNOLOGY

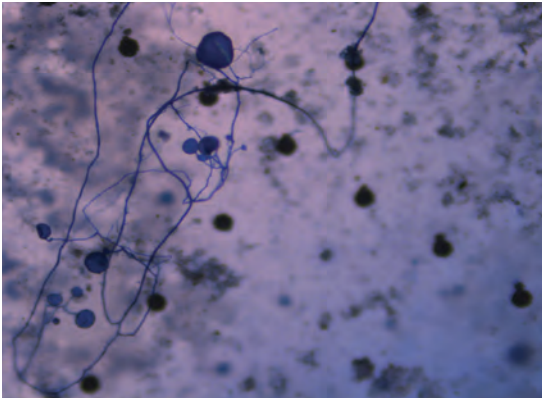
The Agrobiotechnology Section was established in 2008. Its purpose is to provide solutions to arising agricultural problems with the application of advanced, modern techniques using state-of-the-art laboratory equipment. Research activity in Agrobiotechnology encompassed molecular biology, agricultural microbiology and agricultural chemistry projects. The section research activities also involve participation in different EU funding projects such as **HORIZON2020**, **LIFE+** and **FACCE-SURPLUS** as well as **ERANET-MED**.

MOLECULAR PLANT-MICROBE INTERACTIONS AND MICROBIAL ECOLOGY OF AGRICULTURAL ECOSYSTEMS

Soil microbial community structure in different agricultural systems

It has been debated that agricultural systems influence the structure of soil microbial communities, which are the cornerstone for soil fertility. In this research our aim is to gain further insight into how organic and conventional agricultural systems influence soil microbial communities. In detail, next generation sequencing was implemented to assess the bacterial community structure, diversity and richness in barley and apple conventional and organic managed land. The results showed that conventional and organic farming practices had substantial effect on the diversity and the composition of bacterial community. Alpha diversity was higher in organic farming systems compared to conventional in both crops. In addition, the within system variation was high, suggesting that other factors than the agricultural system are shaping the microbial diversity within each crop. For example, organic carbon, phosphorus and potassium in apple orchard soils are significantly associated with the abundance and the diversity of the bacterial community. Bray-Curtis distance metric associated with ADONIS and pairwise comparisons showed the effect of crop type on bacterial soil diversity is higher than that of the system. In addition, the dispersion of the bacterial community within the crops is significant meaning that the bacterial communities within crops are heterogeneous. Finally, Canonical Constraint Analysis (CCA) of bacterial communities in organic and conventional crops showed that pH, organic carbon, Ca, and NH_4^+ are significant driving soil factors, shaping the bacterial composition in the soil. The study is partially funded by the European Union in the context of the LIFE+ORGANIKO (2015-2019) (**M. Omirou, D. Fasoula, I.M. Ioannides, P. Dalias**)

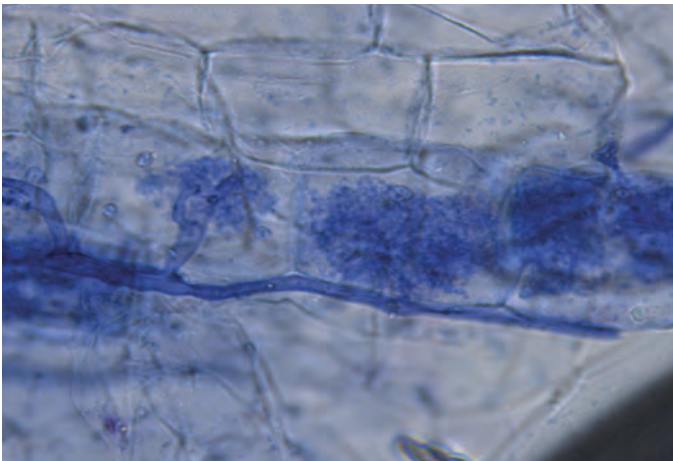




Diversity of mycorrhiza in different crops and plant breeding

The symbiosis of cultivated plants with functional soil microbial guilds is extremely important for agroecosystem productivity, especially in low-input agricultural systems. In this study, we evaluated the abundance and the diversity of mycorrhizal fungi in different underutilised cereals, maize, chickpeas and faba beans. The results showed not only differences between plant species regarding their colonisation with mycorrhizal fungi, but significant differences were also

observed between the different genotypes within the same plant species. Genotypes showing higher colonisation and greater diversity of mycorrhizal fungi in their root system are of interest for plant breeding to treat abiotic stresses. The study is funded by the European Union in the context of the Horizon2020 project under the acronym "DIVERSIFOOD" (2015-2019). (M. Omirou, D. Fasoula, I.M. Ioannides)



Impact of soil water availability and genotype on mycorrhiza diversity of chickpea

Chickpea is one of the most important legumes in the world and could be dramatically affected from water limitation. Chickpea is associated with arbuscular mycorrhizal fungi (AMF) that are known for their contribution to the alleviation of drought stress in plants. In the current study, we evaluated the effect of water limitation in two chickpea genotypes (A345 and A365) and how water limitation affected plant performance and AMF

symbiosis (composition and colonisation), in a microcosm study using a complete randomized design. Water limitation had a detrimental effect only in A345 genotype performance, and this was depended on plant growth stage. On the contrary, the biomass production of A365 genotype was not affected from water limitation 55 days after the initiation of the experiment. This response was associated with AMF colonisation. The colonisation found in the sensitive to water limitation genotype A345 was substantially suppressed in both growth stages while the colonisation of the tolerant, A365 genotype was not affected under drought stress conditions. Multivariate analysis showed that the composition of AMF communities in chickpea was significantly affected by the interaction between growth stage, genotype and water availability ($p < 0.01$). Differential abundance analyses showed that the abundance of specific AMF genera in the tolerant to water limitation genotype A365 was substantially decreased at early growth stages compared to the sensitive genotype A345. These findings highlight that A365 could be less depended on mycorrhizal presence and/or that the AMF colonisers are more efficient acting complementary to the plant inherent drought tolerant mechanisms to alleviate water shortage (M. Omirou, D. Fasoula, I.M. Ioannides)

ENVIRONMENTAL BIOTECHNOLOGY AND MICROBIOLOGY

Characterisation of *PrP* genotypes in sheep and goats

Scrapie is a fatal, neurodegenerative disease of sheep and goats that belongs to the family of transmissible spongiform encephalopathies. Sheep susceptibility to scrapie is associated with polymorphisms in the ovine prion protein (*PrP*) gene at codons 136, 154 and 171. Genomic DNA was isolated and purified from peripheral blood leucocytes using standard procedures. The identification of the allelic variants present in the DNA samples was performed in a simple multiplex PCR reaction and melting curve analysis of the *PrP* gene. Genetic analysis of blood samples of the Chios sheep (755 samples) continued in 2018/19, in order to identify and select genotypes resistant to the scrapie disease. Presently at the ARI, the Chios sheep nucleus unit counts over 350 breeding animals, exclusively of the scrapie resistant genotype ARR/ARR. In addition, the molecular fingerprinting for goats is in progress. In 2018/19, 789 blood samples were tested for scrapie disease genotypes. The data were submitted to the laboratory molecular databank for further analysis. Also, based on scrapie genotyping, a nucleus unit with all the different goat genotypes has been established at the Research Farm of the Animal Production Section. (I.M. Ioannides, G. Hadjipavlou).

Depuration of citrus fruit industry fungicides

The application of the fungicide thiabendazole (TBZ) in fruit packaging plants (FPP) results in the production of effluents that are often disposed in adjacent field sites. These require remediation to prevent further environmental dispersal of TBZ. We assessed the bioaugmentation potential of a newly isolated TBZ-degrading bacterial consortium in a naturally contaminated soil (NCS) exhibiting a natural gradient of TBZ levels (12000, 400, 250 and 12 mg kg⁻¹). The effect of aging on bioaugmentation efficacy was comparatively tested in a soil with similar physicochemical properties and soil microbiota, which was artificially contaminated with the same TBZ levels (ACS). The impact of bioaugmentation and TBZ on the bacterial diversity in the NCS was explored via amplicon sequencing. Bioaugmentation effectively removed TBZ from both soils at levels up to 400 mg kg⁻¹ but failed at the highest contamination level (12000 mg kg⁻¹). Dissipation of TBZ in bioaugmented samples showed a concentration-dependent pattern, while aging of TBZ had a slight effect on bioaugmentation efficiency. Bioaugmentation had no impact on the soil bacterial diversity, in contrast to TBZ contamination. Soils from the hotspots of TBZ contamination (12000 mg kg⁻¹) showed a drastically lower α -diversity driven by the dominance of β - and γ -proteobacteria at the expense of all other bacterial phyla, especially Actinobacteria. Overall, bioaugmentation with specialised microbial inocula could be an effective solution for the recovery of disposal sites contaminated with persistent chemicals like TBZ. (M. Omirou, I.M. Ioannides)

The effects of different soil nutrient management schemes in nitrogen cycling

It is imperative for sustainable agriculture to explore practices and inputs creating low N₂O emission capacity without reducing the productivity of the agricultural system. To evaluate different nutrient management schemes, a microcosm study was conducted to assess the direct N₂O emission from soil. Four different treatments were used to provide a preliminary assessment of N₂O emissions, as well as the concentrations of nitrates (NO₃⁻) and ammonium (NH₄⁺) produced in soil: compost (derived from green plant residues), chickpea residues (green manure) in two different N concentrations (2.6% and 5.5%, respectively) and ammonium nitrate (fertiliser). The soil was thoroughly mixed with the organic amendments and ammonium nitrate, and incubated for 31 days. The emissions of N₂O were higher in green manure with high-N content, as a source of nitrogen in the soil, and were similar to the emissions measured from the chemically fertilised soil. In particular, chickpea residues, with high-N content, exhibited cumulative N₂O emissions, equal to 266.17 μ g N/m², whereas in

fertilised soil the emissions were 267.10 $\mu\text{g N}/\text{m}^2$. On the contrary, the incorporation of chickpea plant residues with low-N content can be an efficient way to minimise the N_2O emissions at 21.63 $\mu\text{g N}/\text{m}^2$. The emissions of N_2O when compost was applied remained relatively low, equal to 5.47 $\mu\text{g N}/\text{m}^2$, and in comparison to soil without any treatment. Overall, a positive association between NH_4^+ , NO_3^- in soil and N_2O emissions was observed. However, this response was treatment-dependent, and the significant positive correlation between NH_4^+ and N_2O emissions was noticed in soils treated with ammonium nitrate, chickpea residues with low N content, as well as untreated controls. On the contrary, the positive correlation observed between NO_3^- and N_2O emissions in soils receiving compost and high N chickpea residues suggests that the different treatments are differentially affecting the processes that are contributing to N_2O emissions in agricultural soils. These findings emphasise that the different nutrient management schemes are differentially affecting the main processes contributing to N_2O emissions in agricultural soils (**M. Omirou, I.M. Ioannides**).



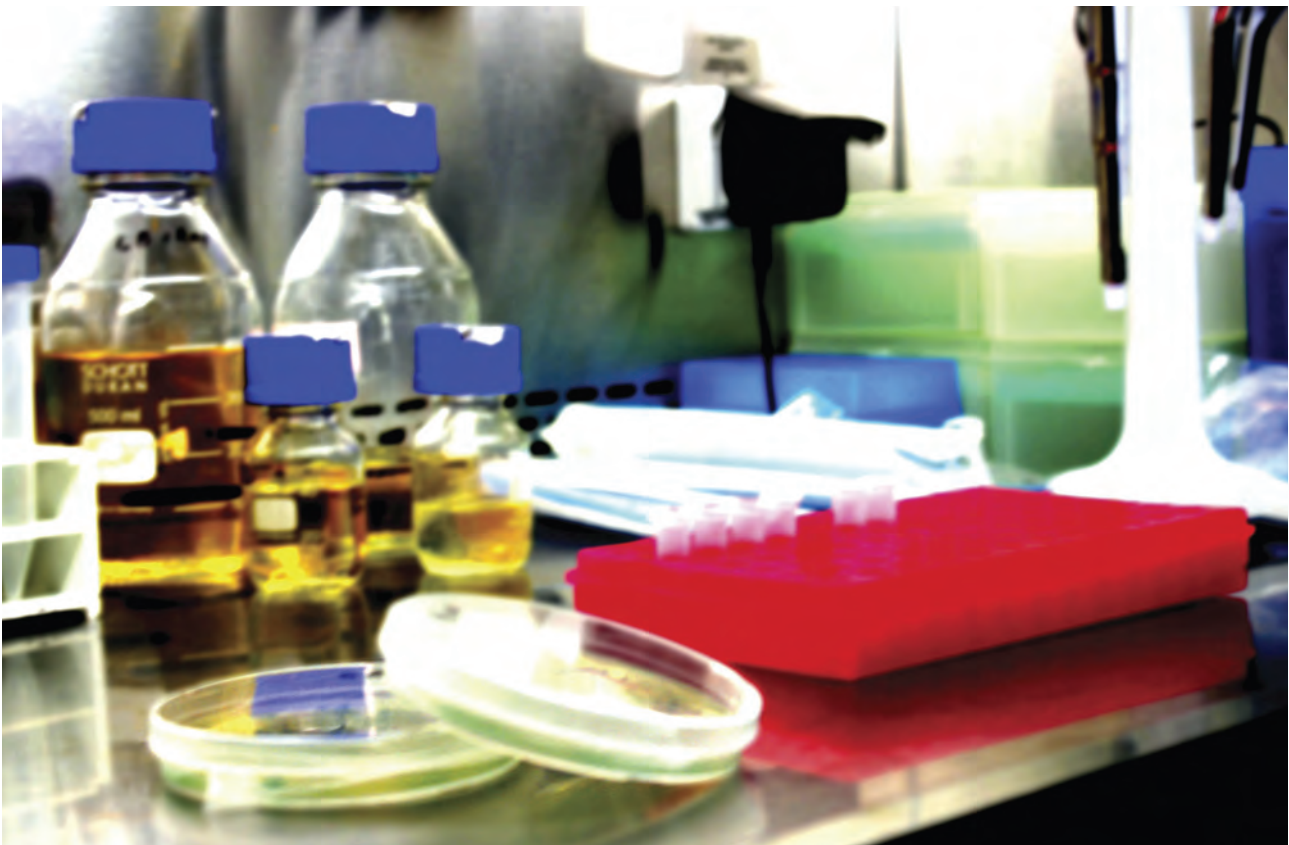
Valorisation of agricultural waste could improve soil fertility and mitigate soil direct N_2O emissions

The emerging need for sustainable management of the increasing quantities of urban and industrial organic waste creates opportunities for the development of alternative strategies for the improvement of degraded soils. The current study was performed to examine the effects of agricultural waste application on soil bacterial community as well as CO_2 and N_2O direct gas emissions. Untreated soils were compared with soils that received the same amount of N (100 $\mu\text{g}/\text{g}$ soil) in the form of ammonium nitrate and organic agricultural waste. In particular, soils were incubated with three different types of organic agricultural waste: orange (OP), mandarin (MP) and banana peels (BP) and ammonium nitrate (F) after adjusting soil water at 70% of its holding capacity. In the current study, soil chemical characteristics, quantitative PCR of denitrifiers (*nirK*, *nirS*, *nosZI* and *nosZII*) and 16S rRNA amplicon sequencing were assessed to examine the links between the soil microbial communities and short-term soil direct N_2O emissions when treated with agricultural waste. The highest soil direct N_2O emissions were recorded in soils that had received ammonium nitrate while soils that had received agricultural waste exhibited substantially lower soil direct N_2O emissions. On the contrary, agricultural waste stimulated CO_2

accumulation as well as the growth of copiotrophic bacterial groups, like Proteobacteria and Firmicutes. Interestingly, direct soil N₂O emissions were decoupled from the density of denitrifier community, while agricultural waste caused a substantial reduction of the relative abundance of bacterial taxa associated with N₂O emissions in the soil. This study provides evidence that agricultural waste could be integrated in a waste management strategy, which *inter alia* includes their direct use in agricultural ecosystems, leading to reduced N₂O emissions (**M. Omirou, I.M. Ioannides**)

National Soil Genetic Resources Bank

Through the RESTART call, the Research Promotion Foundation funded the establishment of the first National Soil Genetic Resources Bank. The aim of this infrastructure is to isolate, characterise and store soil microbes from terrestrial ecosystems of the Republic of Cyprus. Also, a Next Generation Sequencing platform has been established. The objective of the unit is to map and characterise the soil microbiome of Cyprus terrestrial ecosystems. In addition, functional microbial guilds for important crops have been isolated, and breeding processes have been linked with rhizosphere related traits (**M. Omirou, D. Fasoula, D. Neocleous, P. Dalias, I. M. Ioannides**)



VARIETY EXAMINATION CENTER

According to EU legislation, commercialisation of seeds for sowing is only allowed for varieties that are registered in the National Catalogues of the Member States and/or in the Common European Catalogue. Research activity at the Variety Examination Center focused on the execution of field trials required for the registration of varieties in the National Catalogue. For the purposes of registration, an application must be submitted to the Designated Authority (Department of Agriculture) by the breeder, the maintainer or their authorised legal representative residing in Cyprus. The procedure followed for examining varieties prior to their registration in the National Catalogue is described below.

Distinctness, Uniformity and Stability trials

The Distinctness, Uniformity and Stability (DUS) trials take at least two years to complete and include observations on morphological, physiological and agronomic characteristics of varieties, according to the protocols of the Community Plant Varieties Office (CPVO) and the International Union for the Protection of New Plant Varieties (UPOV). During the growing season of 2017/18, one barley variety ('Myrtou'), one peanut variety ('Olivia') and one triticale variety (TR10) were subjected to trials for the first year and in 2018/19 the same varieties for the second year. Also for the growing season 2018/19, two vetch varieties ('Kimon' and 'Zinon') and three barley varieties ('Trikomo', 'Morfou' and 'Lefka') were tested to renew their registration in the National Catalogue. The results were reported to the competent Authority (Department of Agriculture). (**K. Mina**)

Value for Cultivation and Use trials

The Variety for Cultivation and Use (VCU) trials are conducted at several sites representing the environments where the main rain-fed crops are grown. They last for at least two consecutive growing seasons wherein grain yield, yield related characteristics and quality traits are examined. During the 2017/18 and 2018/19 the peanut variety 'Olivia' and barley variety 'Myrtou' were tested for the first and second year, respectively. The results were reported to the competent Authority (Department of Agriculture). (**K. Mina**)

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