



REPUBLIC OF CYPRUS

AGRICULTURAL RESEARCH INSTITUTE

Centre of Excellence
in Agriculture and Environment

REVIEW FOR 2016-2017



MINISTRY OF AGRICULTURE,
RURAL DEVELOPMENT AND ENVIRONMENT
LEFKOSIA

DECEMBER 2018



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Editorial Committee: Dr M.C. Kyriacou
Dr L.C. Papayiannis
Dr G. Hadjipavlou
Dr A. Kyratzis

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Postal Address Agricultural Research Institute
Ministry of Agriculture, Rural Development and Environment
P.O. Box 22016
1516 Lefkosia, CYPRUS

Telephone Lefkosia +357 22 403100
Cables ARI
Telex 4660 MINAGRI CY
Telefax Lefkosia +357 22 316770
Website <http://www.ari.gov.cy>

THE AGRICULTURAL RESEARCH INSTITUTE

The Agricultural Research Institute (ARI) was established in 1962, shortly after Cyprus gained its independence, as a cooperative project between the Government of Cyprus and the United Nations Development Programme Fund, with the Food and Agriculture Organisation (FAO) of the United Nations acting as the executive agency. By the time it was entrusted to the Government of Cyprus in 1967, it 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 Centre 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 Centre. 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 32 scientists, specialised in various disciplines of plant and animal production, 40 technicians, 10 administrative and accounting personnel, as well as permanent and seasonal labour force. 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 effected through radio and television programmes, popular articles in local agricultural magazines and the daily press and through the extension 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 Centre collecting, cataloguing and indexing the agricultural literature published in Cyprus and is also the national CARIS Centre 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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M. Panagi, Clerk

DIRECTOR'S REPORT

"In Search of Excellence"

Under the spectre 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 Organisation 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 to 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 Cyprus Research Promotion 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 are evaluated and in citrus, research work on rootstock evaluation continues. 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 is pursued. Genebank and herbarium activities focus 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. Quantitative and qualitative tests for the presence of genetically modified seeds in imported corn and soybean were carried out. The antioxidant and antimicrobial properties of natural products such as essential oils and plant extracts have been investigated. The impact of treated wastewater 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 are utilised for the prediction of market trends for crop and animal products. Targeted studies, commissioned by the Ministry of Agriculture, Natural Resources 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 centre 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 Centre 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 the tireless efforts of both 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 that 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 progressing with good results for this important crop. The project identified exploitable genetic variation in all landraces under study and 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 is progressing 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 consumers' 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 were performed in five different locations across the island, employing a series of crosses between locally adapted material and promising imported germplasm. Trials using internationally available germplasm, in collaboration with CIMMYT and ICARDA, continued. Following the global trend for 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. The 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 going through the final stages of registration to the National Catalogue, while a new naked barley cultivar is ready to enter the national trials. Innovative breeding 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)



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 stress tolerant varieties. ARI actively participates with its innovative Prognostic Field Phenotyping 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, on the development of Community Seed Banks, and deals also 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)**



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. 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, rain-fed 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 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 from 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 southeast Mediterranean. 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 being very successfully executed, with the involvement of local farmers and extension officers across Cyprus. (**D.A. Fasoula**)



AROMATIC AND MEDICINAL PLANTS

Stevia field trials

In 2017 a new stevia plantation was established at Zygi Experimental Station. From the four varieties examined in the previous programme, variety Candy was selected for the highest leaf production on dry weight basis. The same variety gave also the highest content in total sugars and the best ratio of rebaudioside A: stevioside. The aim of the new programme is to evaluate cultivation techniques which can increase fresh and dry yield and sugar production. The effects of different water regimes, cutting height and fertilisation frequency will be examined in respect to the productive parameters and the hydrophilic antioxidant activity of dried stevia leaves. Finally, economic analysis of the cultivation will be performed, and in the second year a demonstration field will be established.

In 2017 two harvests took place. At the first harvest, the irrigation level affected significantly the plant production and the stevioside content but not the rebaudioside A content. Also, the fertilisation frequency affected only the stevioside content, while the cutting height factor affected significantly the plant height. At the second harvest, irrigation level affected significantly only rebaudioside A. Statistical difference resulted from fertilisation frequency only in plant height and fresh weight, whereas the cutting height significantly affected the concentration of stevioside only. **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 and the stevioside 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 by fertilisation frequency and **Table 3** presents the results of t-test and Descriptive Statistics for plant height, fresh plant weight, dry leaves weight, rebaudioside A, stevioside by cut height. (C. Stavridou)

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

Irrigation level	Plant height (cm)		Fresh weight per plant (g)		Dry leaves weight per plant (g)		Rebaudioside A (mg.g ⁻¹ dw)		Stevioside (mg.g ⁻¹ dw)	
	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
100% ET	64.32 b	30.72 a	243.5 c	60.28 a	41.42 b	7.27 a	74.73 a	48.47 ab	80.66 b	63.34 a
80% ET	54.04 a	31.63 a	180.85 b	57.86 a	37.10 b	7.89 a	81.63 a	56.39 b	68.19 a	57.93 a
60% ET	51.32 a	32.68 a	139.73 a	46.87 a	29.75 a	6.94 a	80.13 a	42.85 a	71.83 ab	64.10 a

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) by fertilisation frequency.

Variable	Fertilisation frequency	M		SEM		t		df		p	
		1 st	2 nd								
Plant height	2 doses	57.79	33.73	1.80	1.25	0.981	2.25	34	34	0.33	0.03*
	3 doses	55.32	29.62	1.76	1.33						
Fresh plant weight	2 doses	194.26	62.28	13.29	4.53	0.68	2.17	34	34	0.51	0.04*
	3 doses	181.88	47.72	12.89	4.92						
Dry leaves weight	2 doses	36.86	8.21	2.00	0.62	0.542	1.87	34	34	0.59	0.07
	3 doses	35.32	6.52	2.02	0.66						
Rebaudioside A	2 doses	78.35	46.07	1.92	2.25	-0.324	-1.62	34	34	0.75	0.11
	3 doses	79.30	52.40	2.22	3.17						
Stevioside	2 doses	79.00	61.43	2.70	2.47	3.24	-0.21	34	34	0.03*	0.83
	3 doses	68.11	62.15	2.00	2.40						

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

*p<0.05

Table 3. 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) by cut height.

Variable	Cut height	M		SEM		t		df		p	
		1 st harvest	2 nd harvest								
Plant height	5cm	59.06	32.57	1.41	1.72	2.08	0.92	34	34	0.04*	0.36
	15cm	54.06	30.78	1.94	0.88						
Fresh plant weight	5cm	204.13	54.83	8.77	19.31	1.80	-0.05	34	34	0.08	0.96
	15cm	172.03	55.17	15.49	23.36						
Dry leaves weight	5cm	38.39	8.27	1.48	2.80	1.68	2.00	34	34	0.10	0.05
	15cm	33.78	6.47	2.31	2.57						
Rebaudioside A	5cm	77.30	46.57	1.66	10.78	-1.05	-1.35	34	34	0.30	0.18
	15cm	80.35	51.90	2.37	12.77						
Stevioside	5cm	76.16	67.38	2.70	7.81	1.39	3.90	34	34	0.17	0.00*
	15cm	70.96	56.19	5.59	9.31						

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

*p<0.05

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 continues. Local clones of pomegranate and several cherry varieties are 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 remain 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

Evaluation of new and traditional table grape varieties under different environmental conditions is undertaken 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. At the Acheleia Station, 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 are evaluated in terms of yield, fruit quality and earliness. The table grape varieties Fantasy Seedless, Black Emerald and the autochthonous varieties Veriko and Sideritis are evaluated at the Acheleia Experimental Station and Autumn Royal at the Saittas Experimental Station. Crimson Seedless is 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 53 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 are evaluated in terms of yield and quality in comparison to the imported varieties Mataro, Cabernet Sauvignon, Merlot, Chardonnay and Sauvignon Blanc. The above varieties are 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

Acquisition of primary and secondary descriptor data continues, according to the International Organisation of Wine and Vine (OIV) standards, for 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. **(S. Savvides)**

Evaluation of traditional wine grape variety Maratheftiko grafted on American rootstocks

Evaluation of the traditional wine grape variety Maratheftiko, grafted on the American rootstocks 110 Richter, 3309 Couderc, 41B, 99 Richter, 420A and 140 Ruggeri, has been performed in the Kilani area. The variety is 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 old and neglected varieties and to promote their future utilisation. Wild vine plants have been recorded at 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 200 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 120 wild vine accessions collected from the above locations. (**S. Savvides**)

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 Zygi 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 the Collection with genetic material from other countries. For identification purposes the evaluation is carried out based on the following elaiographic characteristics of endocarps: shape in position B, length, width in position B, length/width ratio, weight, symmetry in position A, symmetry in position B, number of grooves on basal end, distribution of grooves on basal end, shape of apex in position A, mucron, shape of base in position A, rugosity of surface, position of the maximum transversal diameter in position B as described in the relevant UPOV protocol for olives. (**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 which is 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 post-

harvest behaviour, c) evaluation with respect to fruit harvest maturity and postharvest storage of: 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

Rootstock-modulated yield performance, fruit maturation and phytochemical quality of 'Lane Late' and 'Delta' sweet orange

Graft combinations of sweet orange cultivars Delta and Lane Late on six rootstocks were established on calcareous clayey soil and evaluated for compatibility, yield, and fruit physicochemical quality attributes at three stages of harvest maturity. Citrumelo proved deleterious rootstock to both scions, while GouTou was deleterious to Delta and had low compatibility with Lane Late. Most compatible rootstock for Delta was Sour Orange, whereas all rootstocks except GouTou were equally compatible with Lane Late. Yield and fruit weight were highest on Volkameriana. Titratable acidity was highest on Sour Orange and Carrizo and lowest on Volkameriana. Dominant acids were citric (8.5–11.3 g/L), malic (1.8–1.9 g/L) and succinic (1.3–1.4 g/L). Citrate/malate ratio was lower in Lane Late and declined further with maturation. Acids were highest on Sour Orange and Carrizo. Increased levels of malate (2.07–2.21 g/L) elicited by Volkameriana may constitute an index of inferior sensory quality. Soluble solids were highest on Sour Orange, Carrizo and Cleopatra (9.6–10.6%) and lowest on Volkameriana (9.3–9.7%). Sucrose was the most abundant soluble carbohydrate (33.9–39.9 g/L) and sugar ratios were stable across rootstocks, however sucrose concentration in Delta increased with maturity at the expense of glucose and fructose. Increase in chroma paralleled increase in soluble solids during maturation of Delta but not Lane Late. Fruit phenolics were highest with the least compatible GouTou and lowest with the highly productive Volkameriana. Maximal ascorbate levels were attained at mid-maturity (380.4–450.2 mg/L) and were lowest on Volkameriana (323.4–398.8 mg/L). Considering its overall performance and resistance to Citrus Tristeza Virus, Carrizo appears as a promising rootstock alternative to Sour Orange particularly on calcareous soils. (**M.G. Emmanouilidou, M.C. Kyriacou**)

DECIDUOUS FRUIT TREES

Characterisation and evaluation of local pomegranate clones

The evaluation of selected local pomegranate (*Punica granatum* L.) clones, planted at the Zygi Experimental Station, continued. The purpose of this experiment 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 are examined with respect to yield and quality. (**S. Ioannidou**)

Evaluation of cherry varieties

Ten cherry varieties (*Prunus avium* L.) are examined in terms of production, fruit quality and maturation period. An experimental plantation is established at Saittas Experimental Station. The varieties currently being evaluated are: Bigarreau Burlat, Black Tartarian, Utah Giant, Bigarreau Ferbolous (Verdel), Bigarreau Summit, Bigarreau Fercer (Arcina), Bigarreau Reverchon (Souche sandar), Griotte Du Nord, Bigarreau Lapins and Van. The aim of this work is to evaluate and investigate the behaviour of Cherry varieties under the local agro-climatic conditions of Cyprus, in order to identify varieties of excellent fruit quality. Also the maturity time within the season is evaluated, in order to satisfy market needs for longer periods. (**S. Ioannidou**)

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. The main analytical facility of the Vegetable Crops Section is the Postharvest Technology Laboratory (PTL), 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 in close cooperation with the Vegetable Science Laboratory. 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 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.

Current work focuses on watermelon and melon rootstock-scion relations with respect to productivity, disease-resistance, stress response, quality and postharvest performance. The Vegetable Crops Section has managed national participation in EU Cost Action 1204 (Vegetable Grafting to Improve Yield and Fruit Quality under Biotic and Abiotic Stress Conditions) and has participated actively in the Action's working group on rootstock-mediated effects on vegetable fruit quality. The Section's work on leafy salad crops examined the occurrence of nitrates and nitrites in a wide range of Mediterranean vegetables and how these are modulated by preharvest practices and postharvest conditions. Moreover, extensive work has been initiated on the cultivation and postharvest behaviour of microgreens, which constitute an emerging functional specialty crop globally. Evaluation of wild vegetable relatives comprised trials of male green asparagus cultivars along with select populations of two wild asparagus species (*A. stipularis* and *A. acutifolius*) tested for adaptability to intensive cultivation. Finally, the PTL coordinates the ARI project on the evaluation of an *ex situ* collection of indigenous pomegranate clones.

Biochemical and histological contributions to textural changes in watermelon fruit modulated by grafting

Increased watermelon fruit flesh firmness is systematically incurred with grafting on *Cucurbita* hybrid rootstocks (heterografting). Possible differences in mesocarp cell wall constitution and histology between heterografted, homeografted (self-grafted) and non-grafted watermelon were examined, as well as their contributions to fruit texture. Firmness correlated positively ($r=0.78$, $p<0.001$) with cell density (cells mm^{-2}) which was higher in heterografts (5.83) than homeografts (4.64) and non-grafted controls (4.69) (Fig 3.1). Mean cell size was smallest in heterografts and correlated negatively ($r= -0.75$, $p<0.001$) with firmness. Cell wall material, particularly the water-insoluble pectin fractions associated with firmness, were highest in heterografts. No associations with firmness were found for cell wall neutral sugars and membrane permeability. Higher parenchymatic cell density with higher content of alcohol insoluble residue and more abundant water-insoluble pectin fractions underscore enhanced firmness in heterografts. Possible implication of osmolytes in rootstock-mediated cell pressure regulation warrants further investigation. (G.A. Soteriou, M.C. Kyriacou)

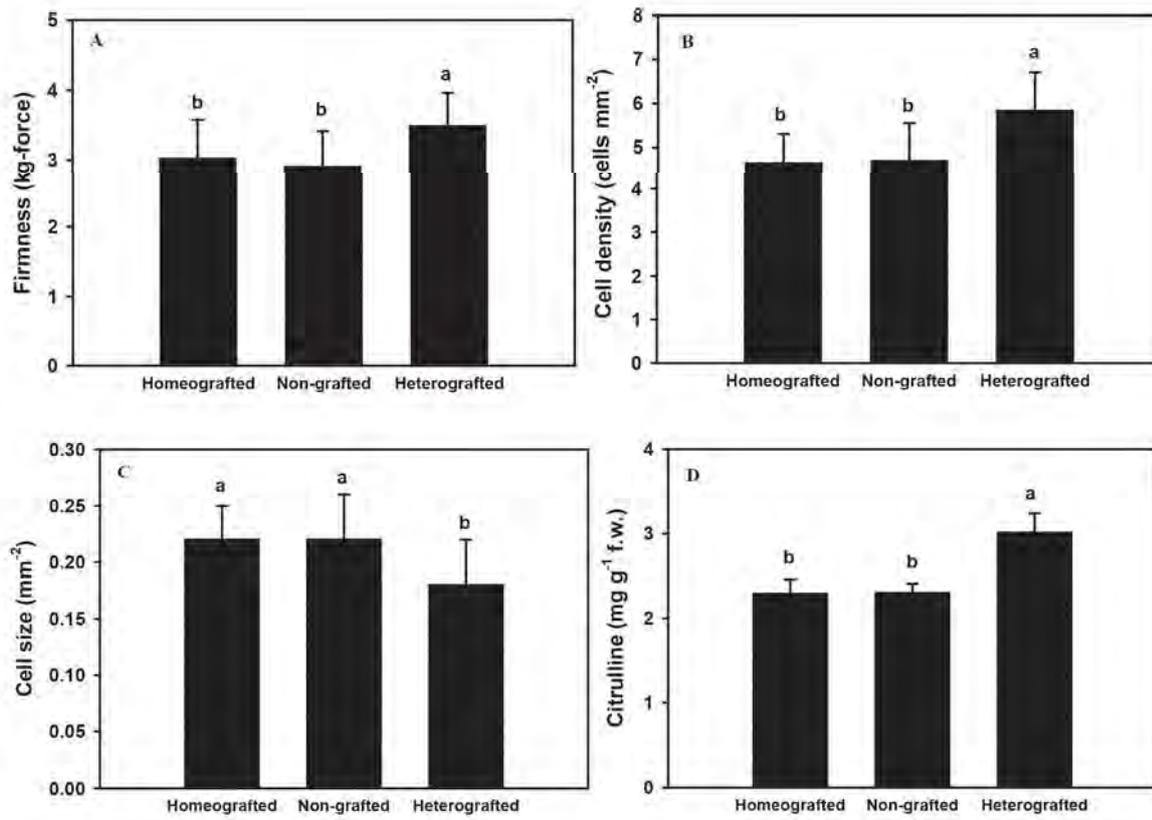


Fig. 3.1. Mean comparisons for fruit flesh firmness (A), cell density (B), cell size (C) and fruit content in citrulline (D) obtained from watermelon cv. Pegasus grown homeografted, non-grafted or heterografted on rootstock N101. All data are expressed as mean \pm standard deviation, $n = 5$. Values followed by the same letter are not significantly different according to Tukey-Kramer HSD Test ($P < 0.05$).

Yield and quality of three mini watermelon [*Citrullus lanatus* (Thunb) Matsum & Nakai] cultivars grafted on *C. maxima* \times *C. moschata* rootstock

Over the last years, the market share commanded by mini (3-5 kg) watermelon cultivars has been growing across watermelon producing countries. In Cyprus this type of watermelon has not been adopted yet by local producers, mainly because of the unfamiliarity of the local market with the product. The objectives of this study have been to evaluate the field performance of three grafted mini watermelon cultivars on a *C. maxima* \times *C. moschata* rootstock. Large fruited diploid cv. Pegasus was used as control. Fructose content of the two triploid mini cvs. Sunday Special and Alicante was higher than that of the mini diploid cv. Modellino, and that of control diploid cv. Pegasus (Table 3.1). On the contrary, cv. Modellino had the highest sucrose content than of all cultivars. Both triploid cvs. Sunday Special and Alicante had higher glucose content than cv. Modellino but not that of control. No significant differences were observed among the triploid and the diploid cultivars with respect to total sugars content and SSC. All cultivars produced similar yield (90 t ha^{-1}). (G.A. Soteriou, M.C. Kyriacou)

Table 3.1. Mean comparisons for fructose, glucose, sucrose, total sugars and soluble solids content at harvest of watermelon fruit from cvs. Sunday Special, Alicante, Pegasus and Modellino grafted on *C. maxima* × *C. moschata* (TZ148) rootstock.

<i>Cultivar</i>	Fructose (g/100ml)	Glucose (g/100ml)	Sucrose (g/100ml)	Total (g/100ml)	SSC (% w/v)
Sunday Special	4.8 a [*]	2.9 a	1.9 c	10.1	11.13
Alicante	4.4 a	2.1 b	2.9 b	10.4	11.11
Pegasus	3.4 b	3.1 a	3.5 b	9.9	10.66
Modellino	3.3 b	1.3 c	5.1 a	10.9	11.30

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

Evaluation of green asparagus hybrids and wild asparagus species 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 of the Aristotle University of Thessaloniki, has set up an experimental trial of five promising male hybrids of green asparagus. Expected outputs of the experiment are: a) the determination of earliness, yield, quality based on physicochemical characteristics and post-harvest performance of the five promising male asparagus hybrids, and b) evaluation of the hybrids as to their suitability for cultivation in arid climates.

Moreover, 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, post-harvest 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* (2 populations). (G.A. Soteriou, A. Kyratzis, M.C. Kyriacou)



POSTHARVEST TECHNOLOGY

Configuration of watermelon fruit quality in response to rootstock-mediated harvest maturity and postharvest storage

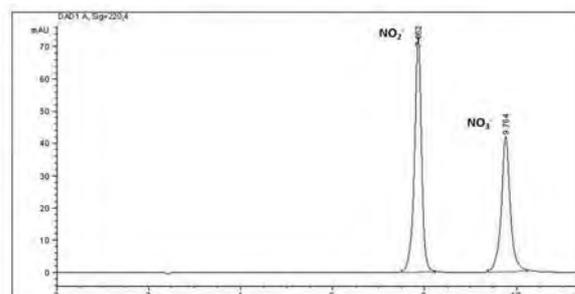
The configuration of watermelon fruit quality was analysed in a multi-factorial approach accounting for the effects of grafting, harvest maturity and postharvest storage. Diploid, seeded, hybrid cv. Pegasus, cultivated as scion on interspecific hybrid squash rootstock TZ148 and as non-grafted control, was stored at 25°C following sequential harvests from the onset of ripening to over-maturity. Delayed rootstock-mediated climax in pulp lycopene and chroma was observed, while both were heightened by postharvest storage when harvest preceded full maturity. Pulp firmness was increased by 46.5% on TZ148, while postharvest decrease in firmness was non-significant. Non-grafted fruits attained their peak in pulp carbohydrate content earlier during ripening. Monosaccharide content declined and sucrose content increased both preharvest and postharvest; overall sugar content declined by 4.3% during storage. Pulp acidity decreased steadily with ripening but was moderately increased by grafting. Citrulline content increased by 12.5% on TZ148; moreover, it climaxed with ripening and declined with storage only in grafted fruit. Grafting enhances pulp texture and bioactive composition. Potential suppression of sugar content as a result of grafting is minimised at full commercial maturity. Brief postharvest ambient storage enhances pulp lycopene and chroma, especially in early-picked fruit, notwithstanding the depletion of monosaccharides and citrulline and a limited deterioration of texture. **(M. Kyriacou, G. Soteriou)**

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



Winter and summer $\text{NO}_3^-/\text{NO}_2^-$ levels of eleven Mediterranean salad vegetables were surveyed using a validated HPLC-DAD method. Nitrates were highest in rocket both in winter ($\bar{x}=3974$ mg/kg) and summer ($\bar{x}=3819$ mg/kg). High NO_3^- accumulators included purslane, chards, dill, coriander and parsley in winter, and dill, chards, coriander, spinach and parsley in summer. Wide intraspecific variability and excess of allowable NO_3^- levels (rocket and spinach) highlight the importance of production methods. Occurrence of NO_2^- (14-352 mg/kg) was most frequent in winter head cabbage. Three experiments examined the seasonal effects of N rate, application method, formulation and postharvest storage on $\text{NO}_3^-/\text{NO}_2^-$ levels of lettuce, rocket and spinach. Nitrogen top-dressing renders spinach and rocket particularly prone to violation of current NO_3^- legal limits, especially when total N-

supply exceeds 200 kg/ha. Postharvest NO_3^- reduction is unlikely before visible signs of quality deterioration and seems to require the exogenous enzymatic activity of microbial nitrate reductase. **(M. Kyriacou, G. Soteriou)**



Appraisal of landraces, underutilised crops and wild edible plants as microgreens

Interest in fresh, functional foods is on the rise, compelled by the growing interest of consumers for diets that support health and longevity. Microgreens garner immense potential for adapting leafy vegetable production to a micro-scale and for improving nutritional value in human diet. Major factors impacting the physiology and crop quality of microgreens include species selection, fertilisation, biofortification, lighting and growth stage at harvest; moreover, postharvest handling and applications, such as temperature, atmospheric composition, lighting and packaging technology influence shelf-life and microbial safety. Effective non-chemical treatments for seed surface sterilisation and antimicrobial action, pre-sowing treatments to standardise and shorten the production cycle and crop-specific information on the interaction of sowing rate with yield and quality warrant further work. Indigenous landraces, underutilised crops and wild edible plants constitute a vast repository for selection of genetic material for microgreens. Modular fertilisation may fortify microgreens' bioactive content and augment their sensorial attributes. Pre- and postharvest select-waveband, intensity and photoperiod combinations can elicit compound-specific improvements in functional quality and in shelf-life. Effective sanitisers and drying methods non-abusive on quality and shelf-life for commercialisation of ready-to-eat packaged microgreens are needed. Genotypic variability in postharvest chilling sensitivity and the interactions of temperature, light conditions and packaging gas permeability need be further examined to establish environments suppressive on respiration but preventive of off-odour development. (Kyriacou, M.C., A. Kyratzis, G. Soteriou)



Evaluation of an *ex situ* collection of local pomegranate (*Punica granatum* L.) accessions as per their qualitative and technological traits, their antioxidant value and storage performance

An *ex situ* collection of local pomegranate accessions collected over a wide range of localities on the island was established at the Zygi Experimental Station in 2010 for purposes of characterisation. Most accessions reached productive age in 2013. Initial evaluation aimed at grouping the clonal material with respect to earliness, mostly on the basis of sugar/acid ratio, fruit weight, skin and juice colour. Sequential sampling was performed between August and November. Preliminary results indicated wide variation in harvest maturity among accessions, spanning the period from end August to early November. Promising, very early and very late clones have been identified. Comprehensive evaluation of the accessions for physicochemical quality attributes is performed,

including soluble carbohydrates, organic acids, anthocyanins, phenolic compounds in the pomegranate juice, characterisation of free radical scavenging potential of pomegranate juice and assessment of juice antioxidant value, seed hardness, texture and fibre content, and fruit storage performance. Also, genetic diversity among the 30 pomegranate genotypes was assessed using 10 microsatellites representing 10 loci. All the microsatellites were polymorphic. The number of alleles per locus ranged from 2 to 5, with an average of 3.3. Our results demonstrate the existence of significant genetic diversity within the collection, which renders the clonal evaluation highly valuable. **(M.C. Kyriacou, A. Kyratzis)**

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 200 new accessions have been collected during the last two years. One hundred and sixty-six accessions have been collected in the context of the CAREMEDIFLORA project and 57 accessions for the Global Tree Seed Bank project. Out of 200 accessions, 108 concern species listed to the Red Data Book of the Flora of Cyprus, 20 accessions concern species listed to Annex II of the Habitat Directive and 18 accessions are from species covered by the Bern Convention.



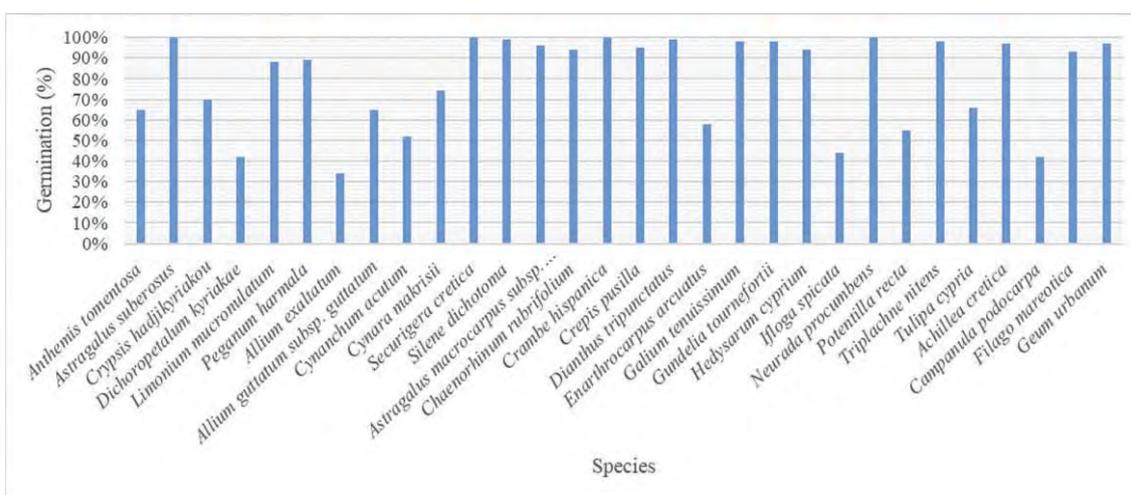
Germination tests have been routinely conducted to assess germination capacity of the CYPARI conserved accessions. Focus has been given to the development of germination protocols for rare plants of the flora of Cyprus. **(A. Kyratzis)**

Conservation Actions for Threatened Mediterranean Island Flora: *ex situ* and *in situ* joint actions

CARE-MEDIFLORA aims to improve the conservation status of threatened plant species of the Mediterranean. It is a project implemented by institutions of six Mediterranean islands and the IUCN/SSC Mediterranean Plant Specialist Group. The institutions involved are 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 are used to produce plant material for *in situ* management actions.

The project is supporting 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 are 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. The duration of the project is 33 months ending at December 2018 and it is founded by MAVA foundation pour la Nature. (A. Kyratzis, M.C. Kyriacou)



Global Tree Seed Bank Project

The "Global Tree Seed Bank Project" is a global initiative, which will secure the future of more than 2,000 of the world's rarest, most threatened and most useful trees. It is funded by the Garfield Weston Foundation and it is coordinated by the Millennium Seed Bank, Royal Botanical Gardens KEW. In Europe, the project will collect and conserve in seed banks at least 200 native European tree species. The national coordinator for Cyprus is the "Nature Conservation Unit" of the Frederic University. Seed collecting has been done by the Department of Forests and the Nature Conservation Unit while seed cleaning and conservation has been done by the ARI genebank. Eighty-eight accessions of native trees and shrubs of Cyprus have been collected. Duplications of these accessions will be sent to Millennium Seed Bank, Royal Botanical Garden, KEW. (A. Kyratzis)

Assessment of Vegetation Indices Derived by UAV Imagery for Durum Wheat Phenotyping Under a Water Limited and Heat Stressed Mediterranean Environment

There is growing interest for using Spectral Vegetation Indices (SVI) derived by Unmanned Aerial Vehicle (UAV) imagery as a fast and cost-efficient tool for plant phenotyping. The development of such tools is of paramount importance to continue progress through plant breeding, especially in the Mediterranean basin, where climate change is expected to further increase yield uncertainty. In the present study, NDVI, SR and GNDVI derived from UAV imagery were calculated for two consecutive years in a set of twenty durum wheat varieties grown under a water limited and heat stressed environment. Statistically significant differences between genotypes were observed for SVIs. GNDVI explained more variability than NDVI and SR, when recorded at booting. GNDVI was significantly correlated with grain yield when recorded at booting and anthesis during the 1st and 2nd year, respectively, while NDVI was correlated to grain yield when recorded at booting, but only for the 1st year. These results suggest that GNDVI has a better discriminating efficiency and can be a better predictor of yield when recorded at early reproductive stages. The predictive ability of SVIs was affected by plant phenology. Correlations of grain yield with SVIs were stronger as the correlations of SVIs with heading were weaker or not significant. NDVIs recorded at the experimental site were significantly correlated with grain yield of the same set of genotypes grown in other environments. Both positive and negative correlations were observed indicating that the environmental conditions during grain filling can affect the sign of the correlations. These findings highlight the potential use of SVIs derived by UAV imagery for durum wheat phenotyping at low yielding Mediterranean conditions. **(A. Kyrtzis)**

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 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 2016 and 2017, 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 2016 and 2017 is shown in Table 4.1. The overall performance of the herd was satisfactory, since milk yield per annual cow was on average 8,506 in 2016 and 7911 in 2017. The total milk produced on farm was 294,311 in 2016 and 260,666 in 2017. The occurrence of abortions peaked in 2016, most likely due to the spread of a relevant bacterial infection, which was managed effectively after consultation with the Veterinary Services. This led to only a single abortion in 2017. Mastitis incidence has improved significantly during 2016-17. (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 378 Cyprus Chios sheep and 327 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 105 days for kids. The breeding scheme is updated yearly and directed toward minimal inbreeding for both sheep and goats. Matings take place two times per year for each species. Production and reproduction characteristics during the period 2016/17 are shown in Tables 4.2 and 4.3. (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 2016 and 2017. 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. Following weaning, 15 male kids from each NS and AR groups were fattened for 70 days. AR goats were milked twice daily. NS goats were milked once daily before and twice daily after weaning. Results in 2016 and 2017 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)

Use of ensiled olive cake in the diet of lactating cows

The project was commenced in 2016 and completed in 2017 and was a joint research project between the Agricultural Research Institute and the Cyprus University of Technology. The research objective was to investigate the addition of the ensiled olive cake (OC) in the diet of lactating cows regarding yield, composition and fatty acid (FA) profile of milk. Twenty-four Holstein-Friesian lactating cows were allocated into two groups of 12 animals (homogenous for age, milk yield, period of lactation and body weight) and given the following iso-energetic and iso-nitrogenous feeding regimes: (a) no inclusion of ensiled olive cake (control group), and (b) inclusion of 5 kg/day/cow (OC group). Measurements of milk yield, milk content (fat, protein, lactose) and FA profile were taken. The results showed no significant differences in milk yield between the two groups. Regarding milk composition, only fat was affected by the treatment. Thus, milk obtained from the OC group was higher ($P < 0.05$) in fat % compared to the control group (average values of 3.5 and 3.2, for the OC and control group, respectively). The lipid unsaturation of milk was increased by the OC addition in the cow diets. The major differences between groups were present in saturated FAs and particularly C10:0, C12:0, C14:0 and C16:0 which

were decreased ($P<0.05$), and mono-unsaturated FAs, and especially oleic acid, which was increased ($P<0.05$) in milk of OC treatment (expressed in g/100g of fat, average values for oleic acid was 23.4 and 20.1 for OC and control group milk, respectively). In contrast, the amount of poly-unsaturated FA was not affected by the feeding treatment. Overall, the results support the use of ensiled OC in diets of high yielding dairy cows as a means to reduce saturated and increase beneficial monounsaturated FAs without adverse effects on milk yield. (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 2016-2017 was 33 and 247, respectively, and that of surplus female lambs was 159. In addition, 10 ewes were issued to farmers. 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 2016 and 2017, molecular genotyping of the selected *PrP* alleles was conducted by the Agrobiotechnology laboratory on more than 789 animals. In this period, the Animal Production section provided the farmers with 45 bucks, 49 goats, 211 male kids and 138 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 (CYprus AGRicultural Genomics cENtre) commenced in 2017. The project is funded by the Teaming (Phase 1) call of the Horizon 2020 framework programme and is coordinated by the Agricultural Research Institute. AGRICYGEN aims at establishing a Centre of Excellence in Animal and Plant Production in Cyprus. AGRICYGEN encompasses 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 will provide the necessary background and know-how to establish the Centre of Excellence in Cyprus.

The AGRICYGEN project aims at the establishment of a Centre 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.

AGRICYGEN ranked fifth out of 208 submitted proposals from 13 countries. Overall, 30 projects received funding in the current Teaming Phase 1 call. During Phase 1, the European Commission grants 400,000 euros for a period of 12 months, in order for the project consortium to demonstrate the potential of the future Centre of Excellence by developing a thorough Business Plan, through effective collaboration and the sharing of expertise. During Phase 2, the successful proposals will receive up to 15 million euros from the European Commission, and a matching fund from the respective national government, for a period of 5-7 years, in order to launch the Centre of Excellence. (G. Hadjipavlou, D. Fasoula, M. Omirou, I.M. Ioannides)



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



Table 4.1. Performance of dairy cattle at the ARI, Athalassa Experimental Farm

Variable	Year	
	2016	2017
Cows calved	16	26
Heifers calved	8	18
Abortions	21	1
Calves born alive	25	43
Calves born dead	0	1
Calves died	0 (0%)	0 (0%)
Calving interval (days)	400	424
Days open	123.5	147.3
Duration of pregnancy (days)	276	275.8
Services/conception	1.75	2.27
Annual cows	34.6	33.0
Milk produced (l)	294 311	260 666
Milk/annual cow (l)	8 506	7 911
Milk fat %	3.63	3.57
Milk protein %	3.22	3.41

Table 4.2. Production characteristics of Chios ewes at ARI (2016/17)

Trait	Yearlings	Adults
No. of ewes lambing	120	473
Lambs born/ewe	1.66	1.96
Lambs born live/ewe	1.55	1.79
Litter weight at birth (kg/ewe)	6.22	7.01
Lambs weaned/ewe	1.39	1.67
Litter weight at weaning (kg/ewe)	18.6	21.8
60-day milk (kg/ewe)	126	142
Total milk (kg/ewe)	311	399
Days in milk	207	277
Milk fat (%)	4.99	5.69
Milk protein (%)	5.03	5.42

Table 4.3. Production characteristics of Damascus goats at ARI (2016/17)

Trait	Yearlings	Adults
No. of goats kidding	142	344
Kids born/goat	1.44	1.90
Kids born live/goat	1.41	1.81
Litter weight at birth (kg/goat)	5.73	7.76
Kids weaned/goat	1.29	1.71
Litter weight at weaning (kg/goat)	17.8	25.1
60-day milk (kg/goat)	104	142
Total milk (kg/goat)	372	485
Days in milk	196	214
Milk fat (%)	3.81	4.52
Milk protein (%)	3.75	3.89

PLANT PROTECTION

Research activities in Plant Protection concern the disciplines of Plant Pathology and Entomology. Under each of these disciplines, specialised studies are conducted to address major crop protection problems associated with particular pests (insects, mites) or diseases (viral, prokaryotic and fungal). In addition, joint multi-disciplinary research projects targeting all important pests and diseases of particular crops are undertaken. All studies 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 new 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 main objective of the programme for the control of CTV, which was initiated in 1992, has been the systematic survey of all citrus and the removal of infected trees and/or groves wherever that is 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). 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 SSCP technique 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 and T. Kapari)



In vitro techniques for elimination of citrus pathogens from infected citrus plants using micrografting, chemotherapy and coldtherapy

In vitro micrografting, chemotherapy and coldtherapy techniques have been using 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/l ribavirin or 30, 40 and 50 mg/l 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 and 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 Xylymbou 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 and 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 and 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 Centres. 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 Aematosyiki 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)**

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)**

Detection of citrus viroids in Cyprus

Citrus exocortis viroid (CEVd) and *Hop stunt* viroid (HSVd) are two important viroids known to infect several plant species worldwide. In recent years, advanced molecular diagnostic tools, such as real-time PCR, have been used widely for the rapid detection of nucleic acid targets. The 5'-nuclease fluorogenic assay, also known as TaqMan real-time PCR, is a powerful and rapid technique providing increased sensitivity and specificity and thus alleviating the need for post PCR manipulations, such as gel electrophoresis. In this study, a real-time reverse transcription (RT) TaqMan polymerase chain reaction (PCR) assay was developed and optimised for the simultaneous detection of CEVd and HSVd. The assay's analytical and diagnostic sensitivity and specificity were evaluated using reference isolates. The multiplex RT-TaqMan PCR assay successfully discriminated the two viroid species from all reference samples and its recorded diagnostic sensitivity and specificity was 100%. In direct comparison, the developed assay presented 1000-fold more analytical sensitivity than conventional. The increased assay sensitivity has allowed the use of alternative template preparation methods such as crude extracts spotted on nylon membranes, offering users a cost effective alternative template preparation method. The developed assay, allows the simple, accurate and cost-effective testing of a large number of plant samples, and can be applied in surveys and citrus certification schemes. **(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 genetic 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)**

Production and maintenance of grapevine healthy plant material

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 then given to the Department of Agriculture for further multiplication and distribution to Cypriot farmers. (L.C. Papayiannis, T. Kapari-Isaia)



Epidemiology and evolutionary studies of criniviruses associated with cucurbit yellows disease

Cucurbit yellow stunting disorder virus (CYSDV), *Cucurbit chlorotic yellows virus* (CCYV) and *Beet pseudoyellows virus* (BPYV) are three whitefly transmitted viruses classified within the genus *Crinivirus* of the family *Closteroviridae*. They cause similar yellowing symptoms in cucurbits and are responsible for high economic losses. In nature, CYSDV and CCYV are transmitted by *Bemisia tabaci* Gennadius, whereas BPYV by *Trialeurodes vaporariorum* Westwood. An extensive study was conducted in order to identify the virus species involved in interveinal leaf yellowing symptoms, leaf brittleness and plant vigor reduction of plant species of the Cucurbitaceae family in Greece mainland, the islands and Cyprus. In addition, a number of weed samples from the surroundings of the symptomatic surveyed crops, as well as whiteflies were also collected in order to assemble epidemiological data. Results showed that both in the mainland and the islands of Greece, CYSDV was the most widespread virus, followed by CCYV and BPYV. *B. tabaci* complex and *T. vaporariorum* species occurrence was evenly distributed. In Cyprus, CYSDV was the predominant virus, followed by CCYV. Both viruses are transmitted only by *B. tabaci*. Approximately 15% of weed samples from 17 different species which belong in 12 botanical families were identified as hosts for one or more of these criniviruses. Finally, sequence analysis of the capsid protein gene of the crinivirus isolates revealed very low levels of genetic diversity further supporting the genetic stability of *Crinivirus* populations. (C.G. Orfanidou, L.C. Papayiannis, P. Pappi, V.I. Maliogka, N.I. Katis)

Host range and transmission properties of *Begomovirus* species involved with tomato yellow leaf curl disease. An epidemiological study was conducted in order to investigate the host plants and the potential role of the whitefly vector *Bemisia tabaci* in the transmission of the *Begomovirus* species involved in the Tomato yellow leaf curl disease (TYLCD). For this purpose, the host range of two *Tomato yellow leaf curl virus* (TYLCV) strains (IL and MLD) and one *Tomato yellow leaf curl sardinia virus* (TYLCSV) isolate was studied using whitefly transmission tests in several plant species. Transmission efficiency of TYLCV and TYLCSV was evaluated using four *B. tabaci* colonies which belonged to the B and Q biotype. The transmission capacity from alternative infected plant hosts to tomato was also studied. Transmission studies showed that TYLCV isolates had a broader host range as well as higher transmission efficiency than TYLCSV (66,3 and 61,2%, respectively). Moreover, TYLCV transmission was somehow correlated with the presence of *Hamiltonella* sp., inside *B. tabaci* insect, as colonies that harbored this bacteria, showed higher transmission rates to tomato plants (68,2 and 71,2%) than colonies that did not harbored *Hamiltonella* sp. (21,2 and 18,6%). At the same time, higher densities of viruliferous whiteflies showed increased transmission rates. Finally, transmission assays from infected secondary hosts, including weeds and other cultivated plants onto tomato, showed that these alternative hosts could serve as important virus reservoirs, contributing significantly to disease outbreaks. (L.C. Papayiannis, N.I. Katis)

Incidence of *Apis mellifera* viruses in Cyprus

In collaboration with the Center of Beekeepers and the Department of Agriculture a new research activity was performed in order to investigate the presence of bee viruses in Cyprus. More than 100 apiaries from the districts of Nicosia, Lemesos, Larnaka, Pafos and Ammochostos were surveyed and approximately 35 adult bees per apiary were randomly collected and stored at -80 °C. A total of 1870 samples were tested for virus presence using molecular based techniques and results showed that *Black queen cell virus* (BQCV) was the most widespread virus with an incidence of 88%, followed by *Deformed wing virus* (DWV) which was detected in 31%. *Acute bee paralysis virus* (ABPV) and *Varroa destructor virus -1* (VaDV-1) were also identified at a very low incidence of 3 and 2% respectively. DWV, ABPV and VaDV-1 were found in mixed infections with BQCV. *Kashmir bee virus* (KBV), *Chronic bee paralysis virus* (CBPV) and *Sacbrood bee virus* (SBV) were not detected. (L.C. Papayiannis, Y. Markou, A. Aggeli)



First report of *Cucurbit chlorotic yellows virus* (CCYV) Cyprus

In 2016, an outbreak of a yellowing disease causing chlorosis and interveinal chlorotic spots on lower leaves was observed in open field cucumber (*Cucumis sativus*), melon (*C. melo*) and watermelon (*Citrullus lanatus*) plants in Nicosia and Limmasol Districts. These symptoms were similar to those caused by whitefly transmitted Criniviruses as well as aphid transmitted Poleroviruses. Leaf samples were collected and total RNA was extracted and tested for the presence of several viruses using RT-PCR. Results showed that plants were simultaneously infected *Cucurbit yellow stunting disorder virus* (CYSDV), a widely spread virus in Cyprus island, as well as with *Cucurbit chlorotic yellows virus* (CCYV), which is identified for the first time. Sequencing analysis showed 99% and 100% identities with the CCYV isolates from Greece and the Middle East. To our knowledge, this is the first report of CCYV infecting cucurbits in Cyprus and our findings support the notion that the virus is spreading in the Mediterranean basin and is an important pathogen in cucurbit crops. (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 fruits 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 selected fruit fly suppression programmes. ARI is one of the institutions from 12 countries that participate in the project. (N.A. Seraphides)

Management of insect pests in pomegranate orchards

In Cyprus, insect pests of pomegranates have not received much attention by researchers, although numerous insect pests have been reported to attack the crop. Among them, the Mediterranean fruit fly *Ceratitis capitata* Wied, the carob moth *Ectomyelois ceratoniae* Zeller, aphids and scales are the most important. The programme is aiming to identify, monitor and develop the best strategy to manage insect pests in Pomegranate orchards. (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 are being investigated. The toxicity of selected insecticides registered for the control of *T. absoluta* in order to determine any insecticide resistance is also evaluated. (N.A. Seraphides, G. Michaelides)



Chemical control of red palm weevil *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae) using the trunk injection method

The endotherapy method for the chemical control of red palm weevil, *Rhynchophorus ferrugineus* Olivier (Coleoptera: Curculionidae) was adopted. Trunk injection using approved insecticidal active ingredients (for limited period of time) against this pest was conducted in the Paphos and Limassol districts for two consecutive years. Twenty-one date palms of the *Phoenix dactylifera* species and 10 palms of the *Phoenix canariensis* species, all of them over 25-30 years old, were used in this study. Specifically designed trunk injection plastic pegs (25 cm-long for *P. canariensis* and 15 cm-long for *P. dactylifera*) were obtained from PROVEFE, S.A. Company (Carretera Vall d'Uixó, S/N, 12526 La Vilavella, Castellón), based in Spain. All instructions regarding installation, preparation of insecticide mixture, application specifications and schedule were proposed by the company (www.sospalm.com). Briefly, two 15 cm-long pegs were used on *P. dactylifera*, while three 25 cm-long pegs were used on *P. canariensis* species. The pegs were inserted in previously drilled trunks in an angle of 45-60°, approximately 1.5-2m above the ground level. The application programme started in late March and on a rotation basis, every 40-45 days, 30-45ml/palm (depending on palm species) of the approved insecticide active ingredients for use against RPW were applied. Active ingredients applied were the following: imidacloprid 20%SL, (Confidor® 200SL, BayerCropScience AG, Germany), abamectin 1.8%EC (Vertimec® 1,8EC, Syngenta Crop Protection, AG, Switzerland) and thiamethoxam 25%WG (Actara® 25WG, Syngenta Crop Protection, AG, Switzerland).

Application of insecticides was based on: a) RPW's population density in the area; b) pheromone trap captures; and c) the intensiveness and frequency of palm damage in the area. Targeted insecticide applications on the selected palms were performed as follows: 1) curative applications: palms with visible signs of damage on leaves and leaves' bases, or palms with sloped leaves or with damaged but not dried central "heart" leaves; 2) preventive applications: palms with no macroscopically visible signs of damage. In both cases, no other control measures had been applied on the selected palm trees prior to or during this study.

The two-year results showed that, 8 out of 21 (38.1%) date palms of the *P. dactylifera* species with visible signs of severe damage at the beginning of applications couldn't recover and finally died, while 2 (9.5%) palms managed to recover from slight damage. Eleven (52.4%) palms without any visible signs of damage remained healthy throughout the study. On the other hand, 4 out of 10 (40.0%) *P. canariensis* palms with or without visible signs of damage at the beginning of applications were totally destroyed by the pest during the 1st year of applications. Visible signs of damage appeared on the other 6 palms during the 2nd year of treatments and eventually these palms were not able to recover and died, indicating once again the preference of the pest to this palm species.



Application of an insecticide using plastic pegs inserted in date palm trunk

The most frequent problem faced using the trunk injection method was the clogging of pegs with gum mainly on date palms, as a result of the injuries caused by gallery drilling of the trunk, preventing this way the insecticide flow within the trunk. (V. Vassiliou)

Molecular diagnostics for detecting pyrethroid and abamectin resistance mutations in *Tetranychus urticae*

Avermectin and pyrethroid resistance mutations (the G314D and the G326E in the glutamate gated chloride channels, and the F1538I in the voltage gated sodium channel) have been reported in the spider mite *Tetranychus urticae*, one of the most devastating pests of protected and open field crops worldwide. We developed three TaqMan molecular diagnostic assays for monitoring the presence and frequency of these mutations in *T. urticae* field populations. The TaqMan assays were validated against known genotypes and subsequently used to monitor the frequency of the resistance mutations in eleven *T. urticae* populations from Greece and Cyprus, with variable history of avermectin and pyrethroids applications. The frequency of the F1538I pyrethroid resistance mutation largely varied among samples, with highest frequencies (75%–97%) detected in four populations derived from protected and open field crops from Crete and Peloponnesus, low frequencies in three populations (2.5%–11%) from Attiki, Cyprus and Crete and not detected in four populations from Crete, Peloponnesus and Cyprus. The frequency of the abamectin resistance mutations G314D and G326E also varied across populations (from 0 to 100%), showing fixation in two populations (N97.5% for the G314D and 100% for the G326E), originating from rose greenhouses from Greece, low frequencies in three populations (5%–12.5%) also originating from rose greenhouses (Crete, Peloponnesus and Cyprus) and not detected in six populations from protected and open field vegetable crops. The TaqMan diagnostics showed higher resolution in detecting specific alleles in low frequency, compared to massive quantitative sequencing approaches previously employed. They can be used, together with classical bioassays, to support evidence - based insecticide resistance management strategies (V. Vassiliou)

Potential use of current natural enemies against invasive insect and mite species

Several insect and mite species have invaded Europe and Israel, causing significant yield losses of agricultural crops of greenhouse and outdoor cultivation and significantly increasing the costs of their management. Invasive species can become a serious problem in the absence of natural enemies, especially during their establishment period on a crop. Especially in greenhouses where natural enemies are absent, insect and mite species can move into the crops and rapidly increase in numbers. Within the greenhouse, good scouting and monitoring is required by examining a number of plants throughout the season, at least twice a week. A thorough examination of few plants in different positions for feeding damage signs or insect excrements or the pest itself is required. This work was supported by COST Action FA1105 - Towards a sustainable and productive EU organic greenhouse horticulture. (**V. Vassiliou**)

How to integrate biopesticides in organic greenhouse growing systems

Biological pest control is usually based on releases of biological control agents, especially in greenhouse growing systems. However, pesticide use is often inevitable for pest control, when pest propagation is too early and too fast, climate conditions are not in favour of beneficial organisms, or suitable beneficials are lacking. Additionally, disease control is still dominated by using fungicides. Many pesticides, even those on a natural basis, have negative effects on natural enemies. Mitigation of undesired side-effects can be achieved by selecting compatible pesticides. A careful assessment of the overall side-effects (including sub-lethal effects) is essential to develop truly selective pesticides for their inclusion in organic greenhouse crops. This work was supported by COST Action FA1105 - Towards a sustainable and productive EU organic greenhouse horticulture. (**V. Vassiliou**)

NATURAL RESOURCES AND ENVIRONMENT

A key feature of recent Section activities is the expansion of studies to new topics related to climate change, the sustainable use of soil and water, precision agriculture and environmental issues in order to assist efforts for sustainable and viable agriculture. The research work of the Natural Resources and Environment Section concerned irrigation and fertilisation of crops, soil fertility, the application of new technologies in greenhouses, the use of treated waste water for irrigation, the use of renewable energy in agriculture and the valorisation of endemic and native species in commercial floriculture and landscaping. An important part of the above research work has been carried out within the framework of cooperation programmes funded by various agencies.

PLANT NUTRITION AND SOILLESS CULTURE

Nowadays, in the light of global warming and severe water shortage in the world, studies on the use of water sources of marginal quality and plant nutrition aspects are matters of great importance for precision agriculture. On the other hand, the issue of salt accumulation in soils or in soilless growing systems with recirculating nutrient solution, especially when the water source used is of poor quality, is critical and requires the implementation of efficient technologies and appropriate mathematical models. A parallel activity concerns the adaptation of irrigation management and plant nutrition schemes to the pressure exerted by climate change, particularly in the Mediterranean region. In this respect, two articles were published recently dealing with the reassessment of water requirements of major irrigated crops in Cyprus. There is also participation in two EU projects whose main objectives are to adapt farming to climate change and limited water resources and to study the comparative advantages of organic versus conventional farming along with other activities (e.g. Students in Research – MERA) organised by the Research Promotion Foundation (RPF).

Simulating NaCl accumulation in a closed hydroponic crop of zucchini: impact on macronutrient uptake, growth, yield and photosynthesis

Zucchini squash (*Cucurbita pepo* L.) plants were grown in a closed-loop hydroponic system and supplied with nutrient solution (NS) containing NaCl at different concentrations (0.7, 3, 5, and 7 mM). The primary aim of the study was to define the relationship between the external and uptake concentrations (UC) of Na⁺ and Cl⁻. A second objective was to determine the UC of macronutrients (i.e., N, P, K, Ca, and Mg) and to test whether they are influenced by the gradual increase of the root zone salinity due to progressive NaCl accumulation. Two experiments were conducted, of which one was used to parameterise an existing empirical model, while the second one was commissioned to test the validity of the determined model parameters. Both Cl⁻ and Na⁺ ions accumulated progressively in the root zone solution over time, showing a tendency to stabilize at final concentrations according to the corresponding NaCl treatment. The relationship between the Na⁺ and Cl⁻ concentrations in the root zone and the Na⁺ /water or Cl⁻ /water uptake ratios was exponential and the model parameters successfully fitted to data from crops cultivated in different growth seasons. This model may be used to monitor Na⁺ and Cl⁻ concentrations in the root environment of zucchini crops as relationships of the plant water consumption. The exposure of plants to NaCl affected the UC of N, K, Ca, and Mg, but the results for some nutrients were not consistent in both growth seasons. The measurements of plant growth characteristics (i.e., biomass, yield, fruit quality, and photosynthesis) revealed that water resources containing up to 3 mM NaCl do not cause unacceptable yield losses in zucchini crops grown in completely closed hydroponic systems. (D. Neocleous, D. Savvas)



Effect of irrigation frequency on growth and production of a cucumber crop under soilless culture

Three irrigation frequencies were applied on a soilless cucumber crop, in a greenhouse located in the southern coastal area of Cyprus. Irrigation scheduling was based on solar radiation and performed whenever accumulated solar radiation energy outside the greenhouse reached 1.3 MJ m^{-2} [High Irrigation Frequency (HIF)], 1.9 MJ m^{-2} [Medium Irrigation Frequency (MIF)] and 3.0 MJ m^{-2} [Low Irrigation Frequency (LIF)]. The amount of water applied was 0.192 kg m^{-2} , 0.288 kg m^{-2} and 0.448 kg m^{-2} for high, medium and low irrigation frequencies, respectively. Appropriately, the total volume of water applied was identical in each of the three cases. In order to study the effects of irrigation frequency on cucumber crops, multiple measurements were taken; the fresh and dry weight of plant organs (i.e. leaves, stem and fruit), marketable fresh yield production, and microclimate variables for a 75-day period, beginning in April and ending in June. The results revealed that the irrigation frequency did not influence the cucumber crop's growth and production. Plants at LIF were facing water stress conditions, as estimated from leaf temperature and stem micro variation measurements. However, HIF increased the transpiration rate of the plants, resulting in less water and nutrient losses. (G. Nikolaou, D. Neocleous, N. Katsoulas, C. Kittas)



Expansion of studies onto new topics related to climate change, the sustainable use of soil and water, precision agriculture and environmental issues

Spatial and temporal variations in evapotranspiration and net water requirements of typical Mediterranean crops on the island of Cyprus. (**A. Christou, P. Dalias, D. Neocleous**)

Comparative analysis of the nitrogen effect of common agricultural practices and rotation systems in a rain-fed Mediterranean environment. (**P. Dalias, D. Neocleous**)

Modelling transpiration of soilless greenhouse cucumber and its relationship with leaf temperature in a Mediterranean climate. (**G. Nikolaou, D. Neocleous, N. Katsoulas, C. Kittas**)

Physiological, nutritional and growth responses of melon (*Cucumis melo* L.) to a gradual salinity built-up in recirculating nutrient solution. (**D. Neocleous, G. Ntatsi, D. Savvas**)

NaCl accumulation and macronutrient uptake by a melon crop in a closed hydroponic system in relation to water uptake. (**D. Neocleous, D. Savvas**)

Using SEBAL to investigate how variations in climate impact on crop evapotranspiration. (**G. Papadavid, D. Neocleous, G. Kountios, M. Markou, A. Michailidis, A. Ragkos, D. Hadjimitsis**)

Advances in hydroponic research. Irrigation management techniques used in soilless cultivation. (**G. Nikolaou, D. Neocleous, N. Katsoulas, C. Kittas**)

European LIFE Programme - Adapt2change

Project actions completed during 2016: 1) Cultivation guides containing information on the soilless cultivation of tomatoes, peppers, eggplants and cucumbers inside the Adapt2change greenhouses. After providing detailed data for each of the aforementioned cases, the guide concludes with an overview of achieved results in view of the programme's objectives. 2) Information about the cultivation testing for the greenhouses of Larissa and Zygi for the Adapt2change project: The heating of the prototype greenhouse using Shallow Geothermal Energy was compared to the standard method used in Cyprus, i.e. using diesel fuel. The results were positive showing that shallow geothermal energy can be used as an alternative RES, contributing to the protection of the environment. The deliverable is a comprehensive and complete list of information-results based on a protocol developed and finalised by the TEI of Thessaly, the Agricultural Research Institute and the University of Thessaly. The deliverable is designed to include information of key project outputs (e.g. guide environmental achievements). (**D. Neocleous, P. Polycarpou**)

<https://www.adapt2change.eu/en/home>



European Programme LIFE - ORGANIKO

The ORGANIKO LIFE+ project started on September 2015 and its duration is 4 years. The aim of the project is to demonstrate the comparative advantages of organic versus conventional farming and their products, using indicators of mitigation efficiency to climate change, agronomic and environmental quality and decreased children exposures to diet-based pesticides. Project actions deliverables in 2016-2017: 1) Review Report on Irrigation Management Scheme. The aim of the deliverable is to provide detailed information on irrigation strategies in organic cultivation of apples and barley. (**D. Neocleous, M. Omirou, D. Fasoula**). 2) Plant Nutrition Fertility Scheme in organic farming systems: Apples and Barley. (**M. Omirou, D. Neocleous, P. Dalias, A. Stylianou, S. Ioannidou, D. Fasoula, I. Ioannides**)

http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n_proj_id=5354

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. Also, a field survey regarding these effects has been carried out in all provinces of Cyprus. In addition, field and hydroponic experiments are carried out in order to evaluate xenobiotic compounds (pharmaceuticals) uptake by plants (tomato, lettuce and alfalfa).

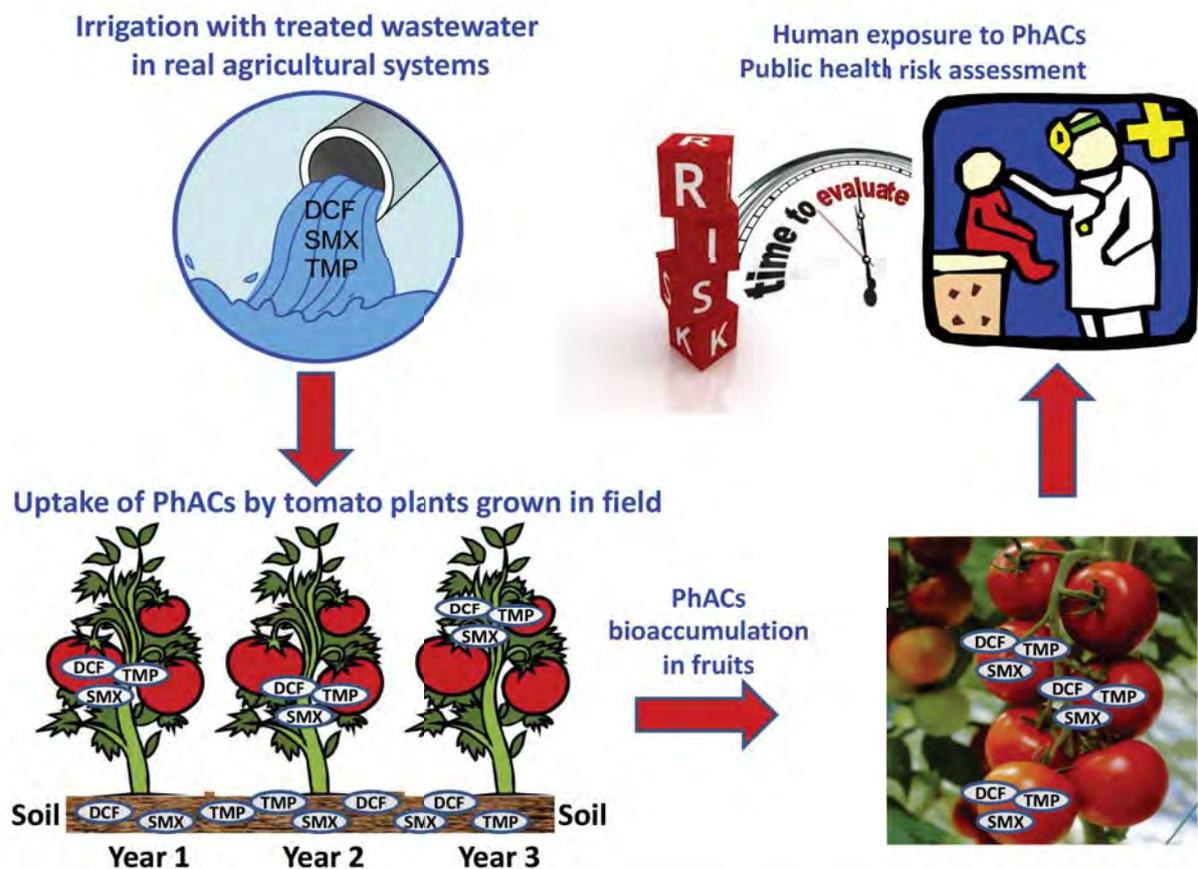
Effects of wastewater applied with discrete irrigation techniques on strawberry plant productivity and the safety, quality characteristics and antioxidant capacity of fruits.

Water scarcity renders reclaimed wastewater (RWW) reuse for irrigation an increasingly common practice worldwide. Comprehensive guidelines and criteria have been established to secure the safety of RWW irrigation, especially for food crops or crops eaten raw. By conducting a short-term greenhouse experiment, the impacts of strawberry crop irrigation with RWW using common irrigation techniques (drip, sprinkler, drip under plastic mulch), as compared to potable water (PW) irrigation, on strawberry fruit quality and safety, and on crop productivity, were assessed. The impact on fruit weight and marketability, as well as on fruit taste (soluble solids, titratable acidity and soluble solids/titratable acidity ratio), antioxidant capacity (ascorbic acid concentration, FRAP, total phenolics and total anthocyanin content), heavy metal content (Cu, Zn, Mn, Co, Ni) and microbial contamination (total coliform, *E. coli*, *Salmonella spp.*, *Listeria spp.*) were evaluated. The results revealed that RWW irrigation did not significantly affect fruit marketability, taste, antioxidant capacity and heavy metal content in comparison to controlled irrigation, regardless of the irrigation technique applied. Fruit heavy metal content was found lower than maximum permissible levels (MPLs) set for fruit safety, whereas no microbiological contamination (total coliform, *E. coli*, *Salmonella spp.*, *Listeria spp.*) of fruits was found in all irrigation water treatments. Overall, the results obtained with regard to the parameters examined highlight the potential for the reuse of the advanced tertiary treated effluent of good quality as a valid alternative for the irrigation of strawberry crops, even with sprinklers. However, further long-term studies are needed in order for such a practice to be regulated. (**A. Christou, G. Maratheftis**)

Long-term wastewater irrigation of vegetables in real agricultural systems: concentration of pharmaceuticals in soil, uptake and bioaccumulation in tomato fruits and human health risk assessment

Wastewater (WW) reuse for vegetable crops irrigation is regularly applied worldwide. Such a practice has been found to allow the uptake of pharmaceutically active compounds (PhACs) by plants and their subsequent entrance to the food web, representing an important alternative pathway for the exposure of humans to PhACs, with potential health implications. Herein we report the impacts of the long-term (three consecutive years) WW

irrigation of a tomato crop with two differently treated effluents under real agricultural conditions, on (1) the soil concentration of selected PhACs (i.e. diclofenac, DCF; sulfamethoxazole, SMX; trimethoprim, TMP), (2) the bioaccumulation of these PhACs in tomato fruits, and (3) the human risks associated with the consumption of WW-irrigated fruits. Results revealed that the concentration of the studied PhACs in both the soil and tomato fruits varied depending on the qualitative characteristics of the treated effluent applied and the duration of WW irrigation. The PhAC with the highest soil concentration throughout the studied period was SMX (0.98 mg kg⁻¹), followed by TMP (0.62 mg kg⁻¹) and DCF (0.35 mg kg⁻¹). DCF was not found in tomato fruits harvested from WW-irrigated plants during the first year of the study. However, DCF displayed the highest fruit concentration (11.63 mg kg⁻¹) throughout the study (as a result of prolonged WW irrigation), followed by SMX (5.26 mg kg⁻¹) and TMP (3.40 mg kg⁻¹). The calculated fruit bioconcentration factors (BCFF) were extremely high for DCF in the 2nd (108) and 3rd year (132) of the experimental period, with the respective values for SMX (0.5 - 5.4) and TMP (0.2 - 6.4) being significantly lower. The estimated threshold of toxicity concern (TTC) and hazard quotients (HQ) values revealed that the consumption of fruits harvested from tomato plants irrigated for long period with the WW applied for irrigation under field conditions in this study represent a *de minimis* risk to human health. However, more studies need to be performed in order to obtain more solid information on the safety of WW reuse for irrigation. (A. Christou)



PhACs, pharmaceutically active compounds; DCF, diclofenac; SMX, sulfamethoxazole; TMP, trimethoprim

Spatial and temporal variations of evapotranspiration and net water requirements of typical Mediterranean crops on the island of Cyprus

Diminishing irrigation water availability and increased crop evapotranspiration (ET) have already been shown to pose threats to agricultural productivity. The Section of Natural Resources and Environment of ARI performed a study aiming to estimate the values and trends of both ET and net irrigation requirements (NIR) of those crops consuming most water due to the size of their cultivated area (citrus and potatoes) in a water-scarce region with typical Mediterranean climate, such as Cyprus, analyse possible spatial and temporal variations of these parameters, and discuss implications of this analysis on agricultural water conservation. A linear regression analysis of ET and NIR values of potatoes and citrus during recent decades in their four main cultivated areas revealed both increasing and decreasing trends for these parameters. Overall, however, the results did not show any change in irrigation water demands for these crops during recent years. In accordance with this outcome, average ET and NIR values of the majority of cultivated crops on the island showed no statistically significant differences between the periods 1976–2000 and 1990–2014. Conversely, this was not the case when data were analysed within each weather station across crops. It is suggested, therefore, that agricultural water resource management schemes should not be focused merely on a regional analysis of changes but that emphasis should be given to site-specific values and trends of ET and NIR estimations, ultimately serving the conservation of agricultural water. (A. Christou, P. Dalias, D. Neocleous)

Melatonin systemically ameliorates drought stress-induced damage in *Medicago sativa* plants by modulating nitro-oxidative homeostasis and proline metabolism

Recent reports have uncovered the multifunctional role of melatonin in plant physiological responses under optimal and suboptimal environmental conditions. We explored whether melatonin pretreatment could provoke priming effects in alfalfa (*Medicago sativa* L.) plants subsequently exposed to prolonged drought stress (7 days), by withholding watering. Results revealed that the rhizospheric application of melatonin ($10 \mu\text{mol L}^{-1}$) remarkably enhanced the drought tolerance of alfalfa plants, as evidenced by the observed plant tolerant phenotype, as well as by the higher levels of chlorophyll fluorescence and stomatal conductance, compared with non-treated drought-stressed plants. In addition, lower levels of lipid peroxidation (MDA content) as well as of both H_2O_2 and NO contents in primed compared with non-primed stressed plants suggest that melatonin pretreatment resulted in the systemic mitigation of drought-induced nitro-oxidative stress. Nitro-oxidative homeostasis was achieved by melatonin through the regulation of reactive oxygen (SOD, GR, CAT, APX) and nitrogen species (NR, NADHde) metabolic enzymes at the enzymatic and/or transcript level. Moreover, melatonin pretreatment resulted in the limitation of cellular redox disruption through the regulation of the mRNA levels of antioxidant and redox-related components (*ADH*, *AOX*, *GST7*, *GST17*), as well via osmoprotection through the regulation of proline homeostasis, at both the enzymatic (P5CS) and gene expression level (*P5CS*, *P5CR*). Overall, novel results highlight the importance of melatonin as a promising priming agent for the enhancement of plant tolerance to drought conditions through the regulation of nitro-oxidative and osmoprotective homeostasis. (A. Christou)

SOIL FERTILITY IMPROVEMENT

Research on fertilisation using organic amendments has been focused on the use of animal manures aiming to provide tools for balancing plant requirements and inputs. The characterisation of hydrochar and the study of the constraints for its use in growing media have also been initiated.

Use of hydrochar in growing media

Peat bogs are valuable habitats that need to be preserved for wildlife and because their drainage and peat exploitation represent a significant source of carbon dioxide emissions. One of the main uses of peat harvested from these bogs is in the growing media industry where peat currently represents about 80% of the materials used annually in Europe. Significant efforts are made, therefore, for peat replacement by suitable alternative materials. Organic products obtained by hydrothermal carbonisation processes (hydrochars) could fully or partially replace peat in growing media if they possess some suitable properties. The ARI evaluated this possibility by focusing on the characterisation of stability of hydrochar produced from wheat. Additionally, as inhibition to seed germination could significantly restrict the eventual use of hydrochar in growing media, a number of seed germination trials were carried out to reveal the magnitude of phytotoxicity in relation to sphagnum peat and biochar and the effect that some simple and cheap pre-conditioning treatments have on the rate of germination. This rate was greatly increased by simply watering the material a few days prior to use or by mixing it with compost. It was shown that the positive effect on seedling emergence should be attributed, at least partly, to the degradation by microorganisms of toxic substances presumably produced during carbonisation. (P. Dalias)



Mineralisation of nitrogen after soil incorporation of the main types of animal manure produced in Cyprus

Manure is a natural byproduct of livestock production and an excellent source of nutrients for crop production. Unlike inorganic fertilisers, manure contributes to soil organic matter increase, and thus on soil structure, aeration, the effective infiltration and water retention capacity.

To maximize benefits and limit the negative impacts of its use, manure should be incorporated in the field at the right time and in the appropriate quantity. The natural characteristics of manure, however, such as its heterogeneity in composition and the variability of its physical properties make its handling a more complex issue compared with that of the inorganic fertiliser. Hence, in a reliable fertiliser programme using manure there is a need of accounting for soil's capacity to supply nutrients and for: 1) the content of manure in ammoniacal nitrogen (N) which is readily available to plant and the content in organic N, 2) the bulk density and moisture content of manure, and 3) the rate or the potential of N mineralisation after incorporation in soil and its relationship with the species of animal from which the manure is coming from, the time of storage/composting and its content in housing material or leftovers of animal forage.

In Cyprus, calculating the proper quantity of manure that should be incorporated in the field as fertiliser is made usually empirically. This leads possibly to non-optimal economic utilisation of manure, to environmental problems mainly due to nitrate leaching and ammonia volatilisation, and to agronomic problems associated with the lack of balance between plant requirements and inputs or the lack of synchronisation.

The research project on manure which will be completed at the end of 2018, aims to cover part of the gaps in knowledge and lack of data related with the use of manure in Cyprus. It focuses on the study of the physicochemical characteristics of manure of the main livestock species, and especially on the estimate of the rate and potential mineralisation of N in relation to the species of animal and the time of storage/composting of manure before its incorporation in the soil. It aims also to standardise and recommend a methodology for estimating the physical and biological properties of manure. Preliminary results showed that the duration of the net N immobilisation phase that usually occurs when manure is incorporated in soil is progressively shortened when the time of manure storage in a pile increases. **(P. Dalias)**



AGRICULTURAL AND ENVIRONMENTAL ENGINEERING

Research in agricultural engineering examines the potential use of biomass for biofuel (biodiesel, bioethanol, biogas, and solid fuel) and energy production under Cyprus conditions. Moreover, a large number of relevant EU and RPF Research Projects are described in detail below.

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. Therefore, alternative energy sources, such as solar, wind, shallow geothermal, and biomass energy, should be considered. The work carried out examined the possibility of using biomass from agriculture and forestry as a renewable energy source. Alternatively, energy plants are investigated so as to select plants that could be used as potential energy sources for solid fuel production, without interfering with the food or feed chain. Biomass can be processed in briquettes, pellets or loose chips. **(P. Polycarpou)**

Adaptation of agricultural production to climate change and limited water resources

The European Life+ project ADAPT2CHANGE: "Adapt agricultural production to climate change and limited water supply LIFE 09 ENV/GR/000296" started in September 2010 and is active until 2016. The TEI Larissa in Greece is the lead partner and the ARI is the Partner for Cyprus. The project is funded by 50% by the EU and additionally involves the University of Athens, TEI Piraeus, and Europliroforisi S.A. The overall project objective

is to show the adjustment of agricultural production to climate change and limited water supply. In particular, it aims to reduce the water used in agricultural production by introducing a method of recycling water through a closed, fully automated hydroponic greenhouse system. The project aims to develop and demonstrate the possibility of increasing agricultural production in a sustainable and environmentally friendly manner in rural areas in Greece and Cyprus, while reducing consumption of energy and natural resources such as water by applying shallow geothermal energy and increasing the income of farmers (**P. Polycarpou, D. Neocleous**).



Assessment of toxic heavy metals concentrations in soils and wild and cultivated plants species in Limni abandoned copper mining site, Cyprus

Mine tailings represent a serious source of soil pollution with public health implications. A survey was performed aiming at (1) assessing the level of toxic and heavy metal mobilisation from the tailing spoil-heap of Limni abandoned mine at Cyprus and the extent of soil contamination to the surrounding area by using pollution indicators; (2) investigating the uptake and accumulation of heavy metals by cultivated crops; and (3) estimating the potential of native wild plant species grown in the studied area to be used in phytomanagement approaches. The tailing spoil heap exhibited significantly higher S, Zn, Cu and Pb concentrations compared to the ones found in control reference samples (RS). The lateral mobilisation of Mg, S, Zn, Cu and Pb resulted to the contamination of the tailing surrounding areas with these metals. Moreover, Mn and Cu concentrations in the tailing and the surrounding areas exceeded the MPLs for agricultural soils. The severe to very severe pollution of the tailing surrounding sides with S, Zn and Cu was also evident by the calculated values of enrichment factor and geoaccumulation index. The values of combined pollution index also uncovered the extremely high pollution of the tailing and the moderate pollution of the surrounding sites with all analysed elements. The concentration of Cd in fig, peanut and lemon fruits, as well as in the grains and straw of barley exceeded MPLs, highlighting the potential Cd-mediated hazardous effects from the consumption of these produces. The examination of heavy metal content in wild native plant species showed that *Inula viscosa* L. has the potential to be used for the phytostabilisation of Cd and Pb, and *Allium ampeloprasum* L. for the phytostabilisation of Pb. Overall, results suggest that the Limni mine tailing and its surrounding sites are highly polluted; thus agricultural activity in the studied area should be prohibited and phytomanagement should be urgently carried out. (**A. Christou**)

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. Moreover, there is a close cooperation with the European Botanic Group Consortium, since the ARI represents Cyprus to the meetings of the consortium. During 2016-17, the joint research activity with the Estonian University of Life Sciences to study the genetic diversity and reproduction ability of a terrestrial orchid was concluded and a paper with the study results was published, while there was also a participation in a research joint activity with the Cyprus Institute for the use of green roofs in the Mediterranean Region.

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

This research project was initiated in September 2015 in collaboration with the Department of Environment and the Forestry Department of the Ministry of Agriculture, Rural Development and Environment, and the Frederick University, under the coordination of Floriculture lab of ARI. The Mediterranean is characterised by a rich flora where unique species occur. Similarly, 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 under 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 and the in-depth study and evaluation of these species. Specifically, research activities concern the collection of the material from the wild where these species naturally occur and the development of propagation protocols both for sexual (from seeds) and asexual (from cuttings) propagation. Furthermore, after the propagation of these plants, the growth and development of these plants will be studied and evaluated so as to create cultivation protocols. (L. Vassiliou)

Joint research activity with the Department of Botany, Estonian University of Life Sciences for the terrestrial orchid *Anacamptis Pyramidalis*

The aim of this research project was to evaluate the genetic diversity and reproduction ability of deceptive terrestrial orchid *Anacamptis pyramidalis* in its distribution range, in Estonia, which serves as the northern border of its distribution area of this species and in the populations located at the southern edge of the range, on the island of Cyprus. In addition, populations from Slovenia and Spain were evaluated. The study revealed no decline in genetic diversity in disjunct populations in Estonia at the northern border of the distribution area of this species, nor in the populations located at the southern range, on the island of Cyprus. Similarly, edge populations were not more differentiated from each other than the central populations in Slovenia and in Spain. The results suggest that the degree of genetic variation is determined by the size of populations rather than geographic location of this species and underlines the impact of long-distance gene flow on the maintenance of genetic diversity in connection with major range shifts in the past. (L. Vassiliou)

Joint research activity with the Cyprus Institute, Energy, Environment and Water Research Center, for testing substrates, plant species and irrigation treatments for developing a zero-water green roof

The aim of this research project, which was carried out between February 2016 and April 2017 was to evaluate the various benefits of the green roofs to the built environment. The objectives of the study were (i) to quantify stormwater retention of two substrate mixtures, (ii) to assess the performance of two plant species (*Euphorbia veneris* and *Frankenia laevis*) under two deficit irrigation treatments (15% and 30% reference evapotranspiration,

ET_o) and (iii) to model the grey area and storage tank size required for a zero-water green roof system. A rooftop experiment was carried out in Nicosia, Cyprus between February 2016 and April 2017, with 16 test beds equipped with drainage and surface runoff tanks, soil moisture sensors and a meteorological station. The two substrate mixtures consisted of perlite: pumice (5-8 mm): pumice (0-8 mm): zeolite: soil: compost, with a volumetric ratio of 0:30:25:15:15:15 (Mix1) and 12:13:27:22:13:13 (Mix2). Mix1 had a depth of 15.5 cm and a dry weight of 121 kg/m², Mix2 had a depth of 17.5 cm and a dry weight of 124 kg/m². The substrate mixture and plant species had no significant effect on the total stormwater retention for the 15-month study period. Average stormwater retention of the 16 test beds was 77% of the 371-mm rainfall. Only 9 of the 19 drainage events exhibited surface runoff, with a total of 0.5 mm over the study period. A survival rate of 38% and 88% was recorded for *Euphorbia veneris* for the 15% and 30% (ET_o) treatments, respectively. *Frankenia laevis* was affected by stress at the beginning of the irrigation period and only the 30% ET_o treatment was applied, for which a 20% survival rate was observed. A 30-year meteorological record (average rain 315 mm/year, reference evapotranspiration 1515 mm/year) was used in a daily water balance model. Results show that a 100-m² roof under 30% ET_o irrigation with collected stormwater, and up to 100% ET_o when water is available, would require a 54.5 m³ tank and 55% of the roof to be grey. Further research could examine a variety of local drought-tolerant species, individually and mixed, under 30 to 50% ET_o irrigation treatments. (K. Charalambous, A. Bruggeman, L. Vassiliou, M. Eliades, C. Camera)

Table 1. Plant performance during the deficit irrigation period (June to October) 2016, for the combinations 15% ET_o-*E.veneris* (Irr15%-EU), 30% ET_o-*E.veneris* (Irr30%-EU) and 30% ET_o-*F.laevis* (Irr30%-FR)

	Unit	Irr15%- EU ¹	Irr30%- EU ²	Irr30%- FR ³
Irrigation June-Oct 2016	mm	118	235	235
Plant survival rate	%	38	88	20
Total new shoots Jun '16	number	133	119	-
Total new shoots Oct '16	number	96	120	-
Total shoots excl. new Jun '16	number	136	125	-
Total shoots excl. new Oct '16	number	108	232	-

¹4 repetitions- 24 plants/1.2 m²

²4 repetitions- 24 plants/1.2 m²

³8 repetitions- 96 plants/2.4 m²



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 precision agriculture which includes topics on applications of information and communication technologies, remote sensing and robotics in agriculture. The Section is also actively involved in EU funded projects. Finally, 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.

COMPUTER SCIENCE

Computers in agriculture - Information sharing

The research project "Information Society in Rural Areas: Knowledge Sharing Using Information and Communication Technology" (<http://ruraldev.ari.gov.cy>) continues the study of current practices related to agricultural research information sharing and new opportunities that emerge by exploiting Information and Communication Technology (ICT). (G. Adamides, A. Stylianou)

Exploring the potential of developing an e-learning platform for farmers within the framework of the Rural Development Programme 2014-2020

The main goal of this study was to explore the views and perceptions of Cypriot farmers and Extension Service personnel, with respect to the possibility of developing an e-learning platform for farmers. To achieve this goal, quantitative and qualitative research methods were concurrently applied (mixed methods approach). In the context of the former, a random sample of 383 farmers was used (Fig. 1), whilst for the latter seven focus groups were held with the total participation of 61 agricultural extension officers. Quantitative research results showed that 36% of the farmers are aware of the concepts of e-learning and e-platform, but only 14% have ever used in the past an e-learning platform. Nevertheless, 67% of the respondents stated that they are willing to use an e-learning platform for farmers, while around half of them exhibit a moderate to high potential capability to use such a platform. Moreover, younger and more educated farmers have higher potential capability and are more likely to be aware of the concepts of e-learning and e-platform. Also, they are more likely to have used an e-learning platform in the past and are more willing to use an e-learning platform designed for farmers. Importantly, none of the farmers of the mountainous areas have ever used in the past an e-platform and they are also the least willing to use an e-learning platform for farmers (Table 1). In addition, the most important training methods for farmers are the asynchronous rather than the synchronous, while the most important thematic unit is plant protection. Qualitative research, through the thematic coding analysis of focus groups, revealed that participants welcome the development of an e-learning platform, however, they maintain some hesitations mainly due to internal structural weaknesses and delay in the adoption of new information technologies by farmers. The results of quantitative and qualitative research were in general consistent and complementary, indicating the dynamics of mixed methods approach. This study recommended the gradual development of the e-learning platform as a complementary tool for agricultural extension. (A. Stylianou, G. Adamides)

Geographic distribution of the sample (n = 383).

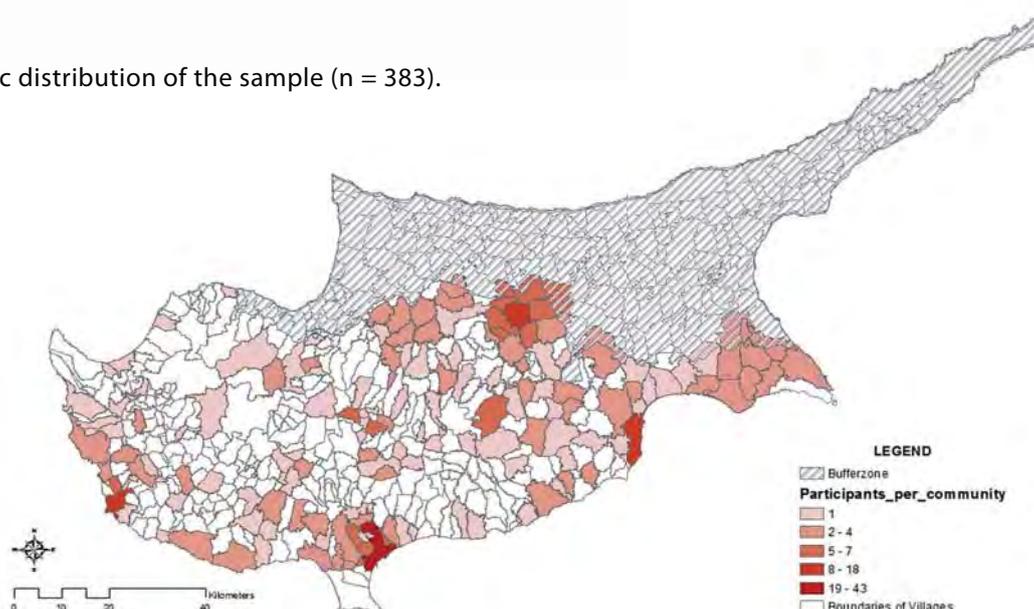


Table 1. Chi-square test for the variables “*e-platform usage*” and “*willingness to use a platform*” with the district of residence.

Variable	District of residence						χ^2
	Nicosia	Larnaka	Limassol	Famagusta	Pafos	Pitsilia ^a	
Platform usage	11.4	21.1	12.5	38.1	13.0	0.0	17.48*
Willingness to use a platform	58.8	61.4	68.8	76.2	88.4	42.3	26.63**

* $p < 0.01$, ** $p < 0.001$. Values are relative frequencies (%) within columns.
^a Pitsilia region was considered as a separate “agricultural district”, since it is treated that way by the Department of Agriculture.

Evaluation of the radio broadcast “The Hour of the Countryside” as an information sharing medium

In collaboration with the Extension Service, a study was initiated for the evaluation of the radio broadcast “The Hour of the Countryside” as an information sharing medium. Specifically, the goal of this study was to evaluate the radio programme “The Hour of the Countryside” as a source of agricultural information and examine the relationship between specific socioeconomic characteristics and listenership. For this purpose, a representative random sample of 383 farmers was used covering the whole territory controlled by the Republic of Cyprus (Fig. 1). The findings revealed that 78% of the farmers are aware of the program’s existence and half of them listen to it. Moreover, older farmers are more likely to be listeners, whilst there is no significant relationship between education level and listenership. Importantly, the farmers of mountainous and semi-mountainous areas are more likely to be listeners. It seems that there is a significant association between the variables “*location/district*” and “*listening to the programme*” ($\chi^2 = 41.46$, $p < 0.001$). Within each district, except Nicosia and Larnaka, more than 50% of the farmers reported that they listen to the radio program. Famagusta and Pitsilia have the highest relative frequencies of listenership (81% and 72%, respectively), whereas Nicosia has the lowest (Table 2). It is evident that although the specific agricultural broadcast has been on air for a long period of time and at the same time other contemporary information sources, like the Internet, have well penetrated into the agricultural sector, radio still enjoys a relative wide listenership amongst farmers. It is strongly recommended that the broadcast be sustained and improved based on farmers’ suggestions and needs, and be regularly assessed. More focus should be given to mountainous and less favoured areas where more traditional information sources prevail. This may implicitly contribute to the development of marginalised areas and to rural development in general. (G. Adamides, A. Stylianou)

Table 2. Chi-square test for listenership and differences between location districts

Listen to the program	n	District					χ^2	V	λ	
		Nicosia	Larnaka	Limassol	Famagusta	Paphos				Pitsilia area
Yes	190	33a (28.9%)	26a b (45.6%)	50b (52.6%)	17b (81.0%)	46b (66.7%)	18b (72.0%)	41.46*	0.33*	0.27*
No	191	81a (71.1%)	31a b (54.4%)	45b (47.4%)	4b (19.0%)	23b (33.3%)	7b (28.0%)			
Total	381	114	57	95	21	69	25			

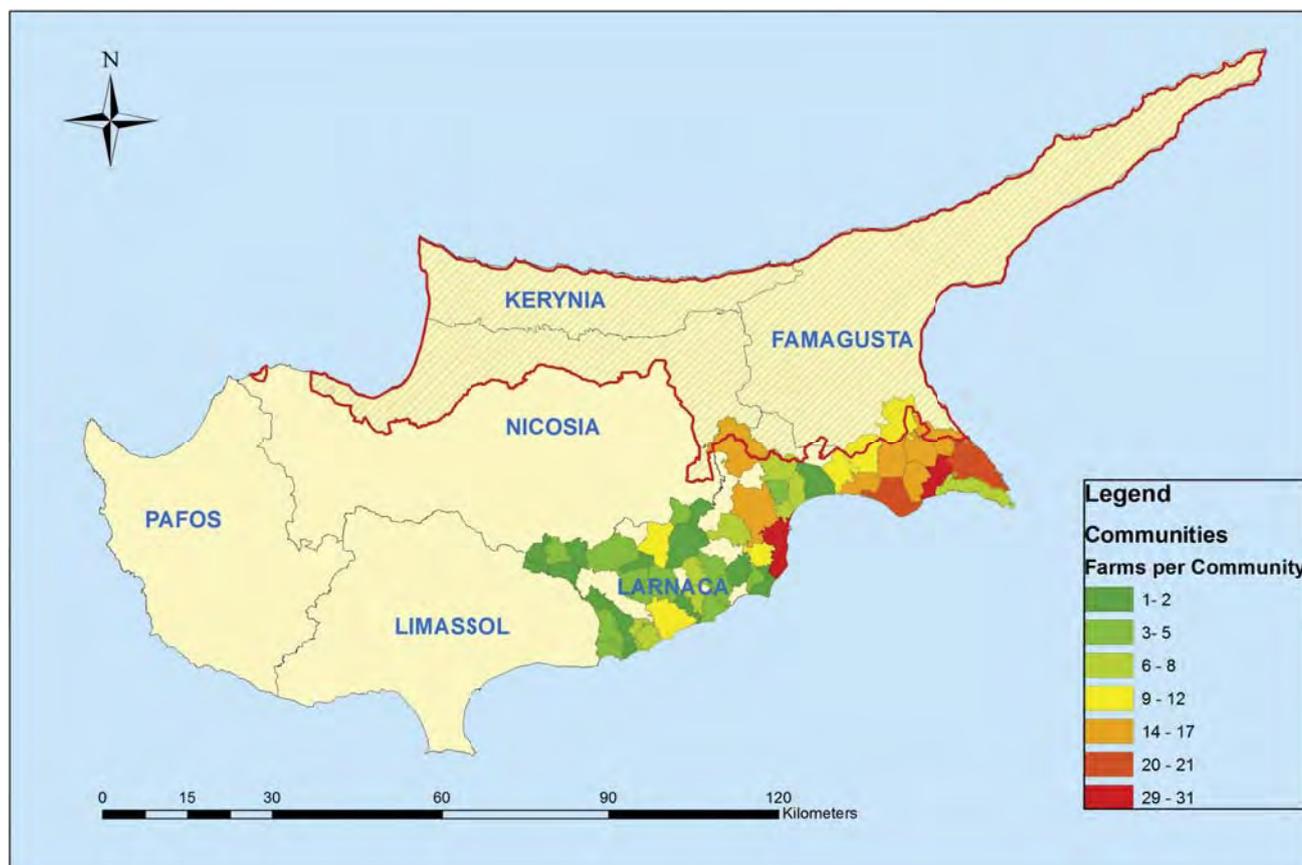
* Significant at $p < 0.01$; V: Cramer's statistic; λ : Goodman and Kruskal's lambda
Different lowercase letters between columns show statistically significant differences at $p < 0.05$

AGRICULTURAL ECONOMICS

Investigating the sustainability of the Agricultural Production System in Cyprus

The ultimate goal of this research project is to examine the environmental, social and economic sustainability of the agricultural production system in Cyprus and its major sub-systems (farming systems), using as case studies the wider rural areas of Larnaka and Famagusta. To achieve this goal, quantitative and qualitative research methods (multi-strategy design) were integrated in order to increase the reliability of the results. The qualitative analysis was successfully completed in 2015 using semi-structured face-to-face interviews on a sample of 100 farm holders. The main qualitative results were presented in the biennial review of the period 2014-2015.

The objective of the quantitative research is threefold: (a) to identify and characterize the major farming systems prevailed in the study area; (b) to assess their sustainability on the basis of the traditional sustainability triad (environment, social, economy); and (c) to compare the main quantitative outputs with the qualitative ones. Within the context of the quantitative approach, a representative sample of 354 farmers was determined using proportionate stratified random sampling method. To obtain the necessary primary data, a well-structured questionnaire was developed, including closed-ended and open-ended questions, grouped into ten sections. After face-to-face meetings with the farmers, 324 fully completed questionnaires were collected (Fig. 2) giving a very high response rate (92%). Each interview lasted approximately 2-3 hours. Subsequently, a large database with over 300 variables and indicators was created in SPSS statistical software. To identify the diverse farming systems in the study area, Principal Components Analysis and Cluster Analysis (Hierarchical and k-means) will be used in tandem, while the systems will be characterised using structural and functional variables which explain the variability between the systems. Next, the sustainability of the identified farming systems will be assessed using an indicator-based sustainability assessment tool developed by the research team. The tool includes simple and composite indicators adapted to the studied systems, and utilizes both visual and numerical integration approaches to present the results. The quantitative research is a work in progress and is expected to be completed in late 2018. (A. Stylianou)



Geographic distribution of the sample in the case study area; Larnaka and Famagusta ($n = 324$).

Economic analysis of Stevia (*Stevia rebaudiana*) in Cyprus

In the context of a research project running by the Plant Improvement Section regarding the cultivation and adaptation of Stevia crop (*Stevia rebaudiana*) in Cyprus conditions, an integrated economic analysis was conducted by the Rural Development Section. Specifically, the goal of the analysis was to assess the economic sustainability of Stevia crop using primary experimental data of the period 2013-2015. The crop was established in the Zygi Experimental Station and was cultivated as a perennial crop. The economic analysis was implemented in three steps. In the first step, a techno-economic analysis was conducted and the main economic results (e.g. net profit) were presented. In the second step, the economic sustainability/feasibility of Stevia cultivation was assessed through cost-benefit analysis, while in the last step sensitivity analysis was conducted and the switching values for the farm gate price (critical variable) were identified. The results were presented under two different scenarios, that is (a) including subsidies (i.e. direct payments) in the gross income; and (b) without considering subsidies in the gross income.

The techno-economic analysis showed that Stevia crop is a profitable investment even when subsidies are not included in the gross income. Specifically, the average (3-year) net profit was estimated at €142,30 and €108,30 per decaire for scenarios (a) and (b), respectively. It is noted that due to the relatively high establishment cost (42% of total cost) and the low yield in the first year of the project, the cultivation of Stevia appears to be loss-making under both scenarios. However, this loss is compensated for by the higher yields and net profits of the 2nd and 3rd years. Likewise, the cost-benefit analysis revealed that Stevia is economically sustainable under both scenarios. Table 3 presents the main outputs of cost-benefit analysis under scenario (b), i.e. when subsidies are not included in the gross income. In the last step, the effect of price variability, *ceteris paribus*, on Net Present

Value (NPV), Internal Rate of Return (IRR) and Benefit-Cost Ratio (BCR) was examined through sensitivity analysis; the switching values for the critical variable expressed as percentages (i.e. % reduction of price in order for the investment to only just break-even) were also estimated. The results showed that, under both scenarios, a relatively small reduction in price [$>14\%$ and $>10\%$ for scenario (a) and (b), respectively] makes Stevia cultivation economically unsustainable indicating a relatively high investment risk. It is strongly recommended that various endogenous and exogenous factors, including selected cultivated (Stevia) variety, high price volatility, market instability and the complete absence of processing facilities and producers' organisations, should be seriously taken into account by the potential farmers-investors. (A. Stylianou, C. Stavridou)

Table 3. Cost-Benefit Analysis of Stevia cultivation without considering subsidies.

Year	Benefit (€)	Present value of benefit (€)	Cost (€)	Present value of cost (€)	Net benefit (€)
0	0.00	0.00	363.05	363.05	-363.05
1	525.00	495.28	501.15	472.78	23.85
2	950.87	846.27	672.66	598.66	278.21
3	1141.87	958.73	755.99	634.74	385.88
Total	2617.73	2300.28	2292.85	2069.24	324.89
NPV (€)			231.05	> 0	
IRR (%)			29	> 6	
BCR			1.11	> 1	

Notes: Discount rate = 6%; year 0: crop establishment; NPV: Net Present Value; IRR: Internal Rate of Return; BCR: Benefit-Cost Ratio.

Agricultural Education and Training

The Rural Development Section provides training to the staff of the Department of Agriculture and to farmers in topics related to agricultural economics, farm management and agricultural marketing. In 2015, the staff of the Section was responsible for developing an important part of the training material which will be used in the framework of the Rural Development Programme 2014-2020 for farmers training. The material developed by the Section concerns the thematic units "Agricultural Production Economics" and "Marketing of Agricultural Products". During the period 2016-2017, the staff of the Section provided training to the staff of the Department of Agriculture (potential trainers) and to farmers participating in specific measures of the Rural Development Programme in two distinct training workshops. (A. Stylianou, G. Papadavid)

EU FUNDED PROJECTS

The staff of the Rural Development Section is actively involved in two LIFE+ projects. The first project titled "Adaptation to Climate change Impacts on the Mediterranean islands' Agriculture" (ADAPT2CLIMA) aims to increase knowledge on the vulnerability of EU Mediterranean agriculture to climate change and to support decision making for adaptation planning. The methodology is based on the deployment of a set of climate, hydrological and crop simulation models for the assessment of climate change impacts on agriculture, as well as, on the development of a decision support tool for the elaboration of adaptation strategies for the agricultural sector. The National Observatory of Athens is the coordinator of the project, while the project partners are the

Agricultural Research Institute, the Institute of Biometeorology of the National Research Council of Italy, the National Technical University of Athens, the Department of Agriculture, Rural Development and Mediterranean Fisheries of the Region of Sicily (Italy) and the Region of Crete (Greece). (**M. Markou, G. Papadavid, A. Stylianou**).

The other 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. In 2016 the 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. (**M. Omirou, D. Neocleous, P. Dalias, D. Fasoula, A. Stylianou, S. Ioannidou, I.M. Ioannides**)

REMOTE SENSING LABORATORY

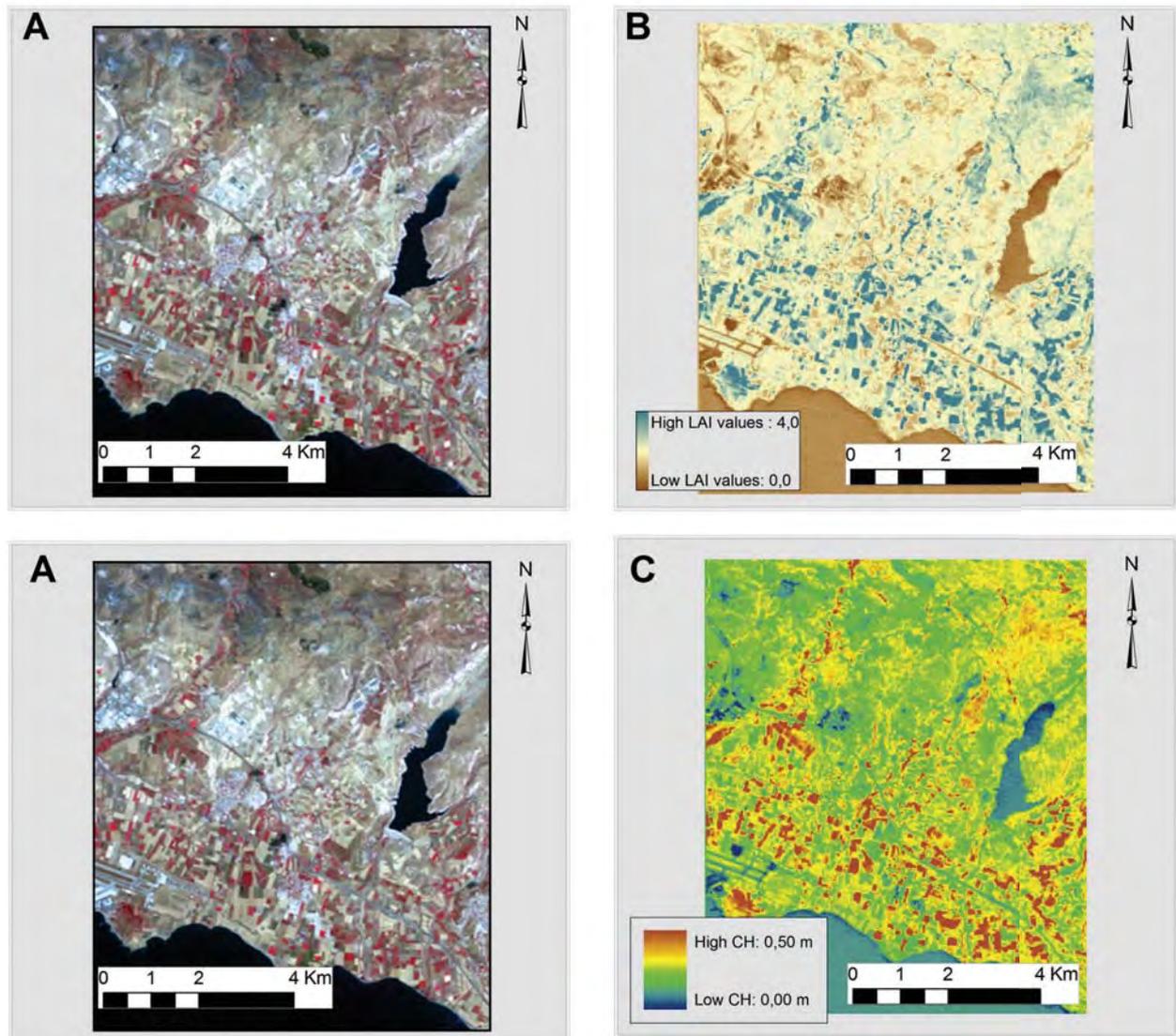
The Remote Sensing Laboratory (RSL) was established at the Acheleia Experimental Station in order to provide scientific data for applications in agriculture and environmental research. The Laboratory has been involved in two research projects regarding crop evapotranspiration and its contribution is expected to prove valuable for all the ARI Sections through collaborative research.

The main purpose of the research project "Effects of Climate Change on irrigation cost of water-intensive cultivations in Cyprus, using remote sensing" is to determine the impact of climate change on crop irrigation needs and how this change affects producers' income. Another research objective is to investigate whether these crops have managed to adapt to the new conditions or if their lifecycle has differentiated according to their irrigation needs and climatic conditions. The research activity regarding the project is already launched with *in situ* measurements on the different crops and of the meteorological conditions. These parameters will become inputs in the form of empirical models for crop evapotranspiration algorithms for estimating Crop Coefficients (Kc) and Crop Evapotranspiration (ETc). (**G. Papadavid, D. Neocleous, A. Stylianou**)

Using SEBAL to Investigate How Variations in Climate Impact on Crop Evapotranspiration

Water allocation to crops, and especially to the most water intensive ones, has always been of great importance in agricultural process. Deficit or excessive irrigation could create either crop health related problems or water over-consumption, respectively. The latter could lead to groundwater depletion and deterioration of its quality through deep percolation of agrichemical residuals. In this context, and under the current conditions, where Cyprus is facing effects of climate changes, the purpose of this study is basically to estimate the needed crop water requirements of the past (1995-2004) and the corresponding ones of the present (2005-2015) in order to test if there were any significant changes regarding the crop water requirements of the most water intensive trees in Cyprus. The Mediterranean region has been identified as the region that will suffer the most from climate change. Thus the paper refers to effects of climate changes on crop evapotranspiration (ETc) using remotely sensed data from Landsat TM/ ETM+ / OLI employing a sound methodology used worldwide, the Surface Energy Balance Algorithm for Land (SEBAL). Though the general feeling is that of changes on climate will consequently affect ETc, the results indicate that there is no significant effect of climate change on crop evapotranspiration,

despite the fact that some climatic factors have changed. Applying Student's T-test, the mean values for the most water intensive trees in Cyprus of the 1994-2004 decade have shown no statistical difference from the mean values of 2005-2015 decade's for all the cases, concluding that the climate change taking place the last decades in Cyprus have either not affected the crop evapotranspiration or the crops have managed to adapt into the new environmental conditions through time. (G. Papadavid)

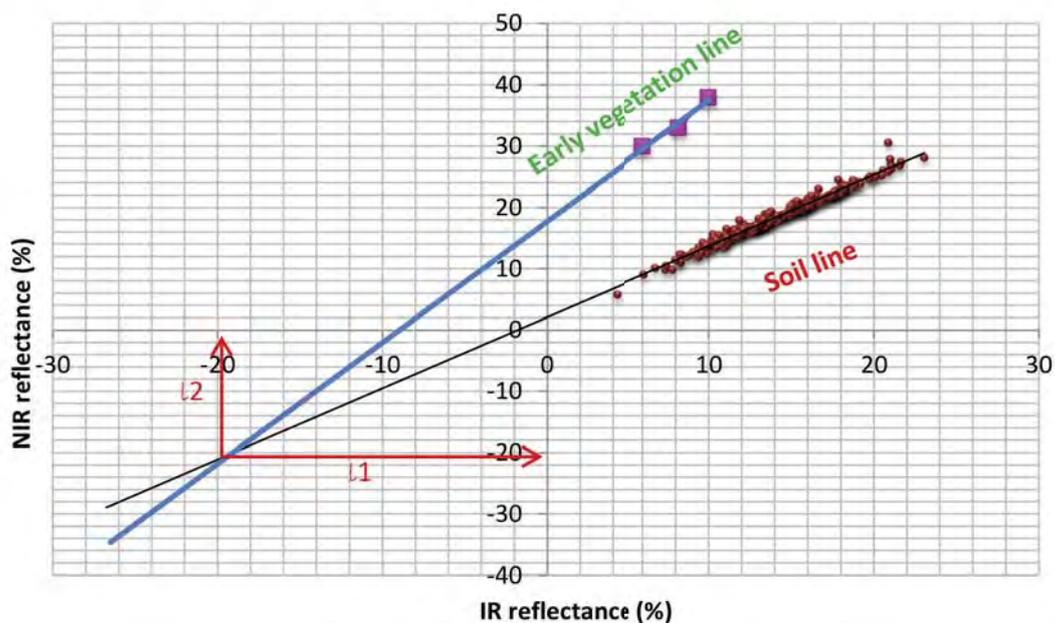


Generation of LAI (B) (in pseudo-color) using Landsat images (A) (Landsat7 ETM+ images).

The use of Earth Observation methods for estimating regional Crop Evapotranspiration and Yield for Water Foot Print accounting.

Remote Sensing can efficiently support the quantification of crop water requirements included in the goal of assessing water footprints (WF) which is to analyze how human activities or specific products relate to issues of water scarcity and pollution and to see how activities and products can become more sustainable from a water perspective. The study provides two examples of how remote sensing techniques are used essentially for providing crop evapotranspiration along with crop yield, two basic parameters, for accounting WF. Two different case studies have been illustrated to define the methodology. The methodology proposed refers to the

Mediterranean's' region conditions and can be applied after inferring the necessary field data of each crop. In this study, the Surface Energy Balance Algorithm for Land (SEBAL) was adopted, under the essential adaptations for local soil and meteorological conditions for estimating groundnuts water requirements. Landsat-5 TM and 7 ETM+ Landsat 8 OLI images were used to retrieve the needed spectral data. The SEBAL model is enhanced with empirical equations regarding crop canopy factors, in order to increase crop evapotranspiration accuracy. Yield prediction plays a vital role in calculating the WF. Having real values than taking reference (or averaged) values from FAO is an advantage that Earth Observation means can provide. This is very important in econometric or any other predicting models used for estimating WF because it reduces their accuracy when using average data. In this context, crop and soil parameters along with remotely sensed data can be used to develop models which can provide users with accurate yield estimations. Crop and soil parameters along with Normalised Difference Vegetation Index (NDVI) have been correlated to examine if crop yield can be predicted and define the actual time-window to predict the yield. Statistical and remote sensing techniques were then applied to derive and map a model that can predict the crop yield. The algorithm developed for this purpose, indicates that remote sensing observations can predict crop yields effectively and accurately. Using the statistical student's T test, it has been found that the predicted values and real values of the crop yield do not have any statistically significant difference. (G. Papadaivid)



Adapting soil-adjusted vegetation index to ground conditions. Employing the modified SEBAL model NIR, near infrared; IR, infrared.

Educational needs and perceptions of the sustainability of precision agriculture: survey evidence from Greece

Precision agriculture (PA) constitutes a dynamic production method which is gaining attention in several parts of the world. Its environmental and economic sustainability has been examined in terms of its ability to reduce the adverse effects of agrochemical use—by regulating their application to the levels needed at the land parcel level—and of its contribution to higher incomes and profitability. At the social level, PA has been linked to collective action although little insight is available regarding the role of various actors and education. This study tackles PA through an assessment of the attitudes of farmers towards the elements of its sustainability and of their educational needs. The analysis of survey data of a sample of young farmers in Greece showed that the majority of respondents were not familiar with PA. Significant differences were found between the attitudes of

knowledgeable and non-knowledgeable farmers, the former demonstrating better acknowledgement of the environmental, economic and social sustainability of PA.

Important educational needs were also detected, with group and individual methods being the most preferred ones for education and information campaigns. The results of the analysis could be of use for the design of Common Agricultural Policy Pillar II measures for the promotion of PA targeting to specific audiences and actors. **(G. Papadavid)**

DISSEMINATION ACTIVITIES

The Section is responsible for maintaining the ARI website and various social media network services. ARI publications since 1965 have been digitised 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>, Twitter http://www.twitter.com/ari_rd, YouTube <http://www.youtube.com/user/aricyprus>, SlideShare <http://www.slideshare.net/ARIWebinars>, and maintains also a web blog at <http://blog.ari.gov.cy>. These services are used to share information about several topics related to ARI activities, while the blog website is used for sharing articles, news and updates from the ARI research activities. It's worth mentioning that there is a steady increase of the users-visitors in our social networking tools. There is a strong positive correlation between the number of published items and the number of visitors. **(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, food science, agricultural microbiology and agricultural chemistry projects. Quantitative and qualitative tests for the presence of genetically modified seeds in imported corn and soybean were carried out. The antioxidant and antimicrobial properties of natural products such as essential oils and plant extracts have been investigated. Research on traditional products derived from grape juice like *sutzioukkos*, *kiofteri* and *palouzes* has been initiated. The impact of treated wastewater use on the microbial load of fruits and vegetables has been explored. Bacteria able to degrade fungicides and herbicides have been isolated and characterised. Screening of local isolated microalgae strains was performed in order to isolate efficient and promising strains for biofuel production and added value co-products. The section research activities also involve participation in different EU funding projects such as HORIZON2020, LIFE+ and FACCE-SURPLUS.

MOLECULAR PLANT-MICROBE INTERACTIONS AND ECOLOGY OF AGRICULTURAL ECOSYSTEMS

The efficiency of symbiotic nitrogen fixing bacteria in cowpea

Cowpea (*Vigna unguiculata*) cultivation is one of the most important legume crops in Cyprus. Its capacity to establish relationships with symbiotic nitrogen fixing bacteria is crucial for the reduction of production costs and the risks of the excess use of nitrogen fertilisers. This study assessed the efficiency of new strains of symbiotic nitrogen fixing bacteria isolated from local cowpea varieties. Totally, thirty strains have been isolated from different cowpea genotypes and evaluated under axenic conditions about their impact on cowpea growth. From these strains, two have been scored as the most promising and selected for further evaluation. A pot experiment using sterile sand as a substrate was employed and a completely randomised design with 10 replicates was implemented to test the efficiency of the inoculation of ARIbrad#7-12-5, ARIbrad#9-17-3 on cowpea performance. The aforementioned strains were compared to a strain ARIbrad#2-15-1 with no effect on cowpea and non-inoculated controls (with and without mineral nitrogen). The highest biomass and N content measured in plants received mineral nitrogen followed by the inoculation treatments. The lowest performance was noticed in non-inoculated plants grown under nitrogen free conditions. Significant correlations between nodule numbers, dry biomass production and N content were calculated demonstrating the beneficial effect of inoculation on cowpea performance. Our group is currently evaluating the ability of these strains to promote cowpea productivity using less nitrogen fertilisers under field conditions. (M. Omirou, D. Fasoula, I.M. Ioannides)

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 core stone for soil fertility. In this research our aim is to gain further insight into how organic and conventional agricultural systems influence soil microbial communities. A factorial experiment (2x3) consisted of the 2 systems and 3 crop rotation schemes established at the experimental Station of Acheleia. The experiment is a randomised complete block design in a split-plot arrangement with 3 replicates. First results showed that both factors have a significant effect on soil microbial communities while this is also related to phosphorus levels in soils. The research continues and the results are expected to reveal the differences between the two systems and test the hypothesis that specific microbial guilds are favored by crop rotation scheme. The study is partially funded by European Union in the context of the LIFE+ORGANIKO (2015-2019). (M. Omirou, D. Fasoula, I.M. Ioannides, P. Dalias)

Diversity of symbiotic nitrogen fixing bacteria and mycorrhiza in different species

The symbiosis of cultivated plants with functional soil microbial guilds is extremely important for agroecosystems productivity especially in low input agricultural systems. In this study we started the description of the abundance and the diversity of symbiotic nitrogen fixing bacteria and mycorrhiza in different underutilised cereals, maize, chickpeas and faba beans. The study is funded by European Union in the context of the Horizon2020 project with acronym "DIVERSIFOOD" (2015-2019). (M. Omirou, D. Fasoula, I.M. Ioannides)

***Bradyrhizobium* inoculation alters indigenous AMF community assemblages and interacts positively with AMF inoculum to improve cowpea performance**

Legumes are a major component in sustainable agricultural systems since they can fix atmospheric nitrogen and form effective associations with both nitrogen fixing bacteria (NFB) and arbuscular mycorrhizal fungi (AMF). However, the impact of NFB inoculation on the indigenous AMF community structure in legumes has been overlooked. In the current study, we investigated the influence of a *Bradyrhizobium* isolate together with a commercial mycorrhizal inoculum on the performance of cowpea, along with its endophytic mycorrhizal community structure. A three-way factorial randomised design was established in sterilised and non-sterilised soils, including control plants (without inoculation), inoculated plants with a *Bradyrhizobium* (NFB) strain, a commercial mycorrhizal inoculum (AMF) and their combination (AMF+/NFB +). All inoculation treatments under sterile and non-sterile soil conditions resulted in a significant increase in the shoot biomass, which was positively correlated with AMF colonisation, and the number of nodules found in cowpea roots. Mycorrhizal colonisation and nodule formation in control plants grown in non-sterilised soils, suggested an active and functional local mycorrhizal and rhizobial community in the soil, which was further supported by the molecular fingerprints. Growth of control plants in sterile soil resulted in lower shoot biomass that was in line with the absence of the respective microbial assemblages. Interestingly, the local AMF community pattern of cowpea roots was drastically altered after the NFB application. Molecular fingerprinting, through cloning of PCR amplified sequences of 18sRNA revealed that cowpea plants were colonised by *Rhizophagus*, *Funneliformis*, *Claroideoglossum* and *Paraglossum* related species. The results support the notion that the introduced *Bradyrhizobium* strain interacted drastically with the indigenous AMF community, leading to a more diverse colonisation pattern of cowpea roots. These findings enhance our understanding of how these microorganisms interact to affect plant performance and increase agricultural sustainability. (M. Omirou, D. Fasoula, I.M. Ioannides)

FUNCTIONAL FOODS AND FOOD SAFETY**Impact of drought stress on *Eruca sativa* Mills secondary metabolites**

Rocket salad (*Eruca sativa* Mills) is one of the major leafy vegetables produced worldwide and has been characterised as a rich source of chemoprotective glucosinolates (GSL). A pot experiment was conducted applying drought stress for 11 days while plants normally irrigated served as control. Drought stress had a detrimental effect on *E. sativa* performance. Photosynthetic machinery was significantly suppressed while total N and P content in rocket leaves were reduced. Glucosinolate content and their corresponding biosynthetic genes were evaluated (M. Omirou, D. Fasoula, I.M. Ioannides, A. Christou)

Chemical composition and microbial guilds of traditional products from grape juice: Sutzoukkos, kiofteri and palouzes

Traditional products obtained from grape juice such as sutzoukkos, kiofteri and palouzes constitute an economically important sector of Cyprus rural areas. The aim of this study was to identify the chemical composition of these products and evaluate their microbial community structure. Our hypothesis was that the

use of different local varieties (Xynisteri and Mavro) during the preparation of these products affects their chemical and microbiological characteristics. During this study we also recorded the preparation process that is implemented by the producers of these products. The grape variety used for the preparation of these products has a significant effect on their chemical composition and especially in polyphenols (anthocyanins and stilbenes). Finally, an analytical method for the detection of the addition of sucrose was developed and tested in real samples. (**G. Maratheutis, I.M. Ioannides, M. Omirou**)

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 (874 samples) continued in 2016/17, in order to identify and select genotypes resistant to the scrapie disease. Presently at the ARI, the Chios sheep nucleus unit counts over 400 breeding animals exclusively of the scrapie resistant genotype ARR/ARR. In addition, the molecular fingerprinting for goats is in progress. In 2016/17, 685 blood samples were tested for scrapie disease genotypes. The data were submitted to the laboratory molecular data bank for further analysis. Also, based on scrapie genotyping, a nucleus unit with all the different goat genotypes is being established at the Research Farm of the Animal Production Section. (**I.M. Ioannides, G. Hadjipavlou**)

Isolation and characterisation of pesticide degrading microorganisms and their formulation

Contamination of waters by xenobiotic compounds such as pesticides presents a serious environmental problem affecting European water resources. The aim of this work has been to evaluate the ability of several bacterial species for biodegradation of the pesticides imidacloprid, pendimethalin, imazalil, thiabendazole and ortho-phenyl phenol in batch liquid cultures. Several bacterial species have been isolated and screened for their ability to metabolize these pesticides via the enrichment process. Despite the relatively high persistence of the tested pesticides, the results obtained so far showed that *Acinetobacter* and *Sphingomonas* like species have a high capability for biodegradation of these compounds. These isolates could prove valuable as active pesticide-degrading microorganisms, increasing the efficiency of pesticide bio-purification systems such as biobeds or specifically designed bio-filters. The degradation product of TBZ derived from *Acinetobacter* activity was identified. The active strains are currently evaluated in different formulations in order to scale up their application in biobed systems. (**M. Omirou, I.M. Ioannides**)

Bioaugmentation of thiabendazole-contaminated soils from a wastewater disposal site: Factors driving the efficacy of this strategy and the diversity of the indigenous soil bacterial community

The application of the fungicide thiabendazole (TBZ) in fruit packaging plants (FPP) results in the production of effluents which 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**).

Citrus industry wastes shift the soil bacterial communities structure in soils

Citrus industry generates a substantial amount of wastes across Mediterranean and their application in agriculture could be a valuable tool to sustain agro-ecosystems productivity and an environmental friendly approach for their management. In this microcosm study we examined the impact of orange, mandarin and banana peels on soil bacteria community and compare it to fertilised and non-fertilised controls. Diversity indexes and bacterial community structure was assessed using next generation sequencing in two sampling points. Both type of waste and time had strong and interactive effects on the bacterial community of soils. The lowest diversity was noticed 5 days after the initiation of the experiment in soils that received agricultural wastes. The lowest diversity was noticed in soils received orange peels followed by those received banana and mandarin peels. However, during time the bacterial diversity increased significantly and it was similar with that measured in control and fertilised soils. Copiotrophic bacterial groups were stimulated in soils treated with agricultural wastes while the abundance of most bacterial Phyla detected was suppressed. This study shows that agricultural wastes derived from citrus industry have a strong but temporal effect on bacterial community structure and represents a basis for future research regarding the impact of different organic amendments on bacterial community networks (**M. Omirou, I.M. Ioannides**).

Soil nitrous oxide emissions under different nutrient management schemes

Intensive livestock production and urban wastes generate large amount of wastes which are composted and typically reused as fertilisers in agricultural ecosystems. In Cyprus, application of manure and chemical fertilisers often results in high nitrogen inputs generating a surplus of available nitrogen that can stimulate large nitrous oxide emissions. On the contrary, composted material doesn't increase N soil content however increases organic C thereby improving soil structure and functioning. The present study, included barley, vetch and pea production fields. Livestock manure, compost, ammonium nitrate was applied in a split-plot experimental design and compared to non-treated controls. Nitrogen inputs, N₂O emissions, crop N content and soil available nitrogen were assessed over two growing seasons. N₂O emission was significantly affected by type of nutrient management scheme, crop type and year. The emission factors in the different systems were between 0.07 and 0.24% and this was associated with the environmental conditions and particularly soil moisture. The variability of N₂O fluxes and the cumulative N-N₂O emissions was likely due to differences in nitrogen inputs and agricultural system management. The higher cumulative N-N₂O emissions were recorded in chemical fertilised plots in all crops followed by manure and compost. Under control conditions, the highest emission was noticed in vetch followed by pea and barley. This study showed that the use of organic amendments in agricultural systems reduces N₂O emissions under semi-arid conditions (**M. Omirou, I.M. Ioannides**).

Development of microbial tools for sustainable food production

Exploitation of microbes as biofertilisers is considered as a promising biotechnological tool alternative to chemical fertilisers in agricultural sector due to their extensive potentiality in enhancing crop production and food safety. In this study we aim to isolate, characterize and test functional microbial groups isolated from Cyprus agricultural ecosystems. The study is funded by European Union in the context of the EranetMed project with acronym "SUPREME" (2017-2020) (**M. Omirou, I.M. Ioannides**).

VARIETY EXAMINATION CENTRE

According to EU legislation, commercialisation of seeds for sowing is only allowed for varieties that are registered to the National Catalogues of the Member States and/ or to the Common European Catalogue. Research activity at the Variety Examination Centre focused on the execution of field trials required for the registration of varieties to 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 2015/16, one barley variety (Myrtou) was subjected to trials for the first year. In the 2016/17 growing season, the barley variety was tested for the second year and a peanut variety was tested for the first year. 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 rainfed 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 2015/16, was tested for the first growing season. In the 2016/17, the barley variety Myrtou was tested for the second growing season but because of drought conditions the results were not adequately and the trials will be repeated next year. In 2016/17 the peanut variety was tested in two locations for the first year. The results were reported to the competent Authority (Department of Agriculture). **(K. Mina)**

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Other Publications

- Adamides, G., A. Stylianou, P. Kosmas, I. Berzina, A. Mendonça, O. Galea, D. Sdrali, I. Galatoulas, and C. Apostolopoulos. 2016. Improving skills for Smartfarming as an innovative tool for rural development and economic growth. http://www.smartfarmerproject.eu/deliverables/e_book_EN.pdf. ISBN 9789963160198 (e-book)
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- Stancalie G., A. Nertan, P. Struzik, L. Toullos, M. Spiliotopoulos, G. Papadavid, and A. Tarquis. 2016. Assessment of the most appropriate set of vegetation indices and biophysical variables in the context of a cost effective solution to monitor water stress using satellite data. In: How the Study of the Water Foot Print of Agricultural crops can benefit from the use of satellite remotely sensed data. 2016 (COST EUROAGRIWAT) ISBN 978-80-85754-38-4
- Vassiliou, V.A., E. Palevsky, and E. Richter. 2016. Potential use of current natural enemies against invasive insect and mite species. Factsheet No14. COST Action FA1105 "BIOGREENHOUSE".
- Kapari-Isaia, T., and L.C. Papayiannis 2017. Viruses and related pathogens of Citrus in Cyprus and high risk

emerging diseases of citrus cultivation. *Enimerotiko Deltio* 7, Agricultural Research Institute Publications (ISSN 1986-1370). Nicosia, Cyprus (in Greek). 28p.

Soteriou, G.A., M.C. Kyriacou, and L.C. Papayiannis. 2017. The physiological decline of melon. *Enimerotiko Deltio* 8. Agricultural Research Institute Publications (ISSN 1986-1370). Nicosia, Cyprus (in Greek). 23p.

SEMINARS

A total of three seminars and day conferences were presented in 2016 and four in 2017. The seminars were chaired by Mr. A. Kyratzis and Mrs. M. Emmanouilidou

March 4, 2016	E. Maloupa and Yiannis Zalidas: Practical workshop on aromatic and medicinal plants
June 24, 2016	P. Polycarpou and associates - Workshop: Applications of Shallow Geothermal and Solar Energy in Greenhouses
September 30, 2016	L. Papayiannis: Aphid transmitted viruses infecting crops in Cyprus
March 2, 2017	A. Christou, P. Hadjegeorgiou, P. Karaolia, E. Hapeshi, L. Ioannou-Toffa, S. Michael, V. Beretsou, D. Fatta-Kassinou: Challenges and opportunities in reclaimed wastewater reuse for irrigation – Day conference
June 8, 2017	A. Stylianou, M. Omirou and associates: The organic market in Cyprus: from farm to fork – The results of LIFE+ ORGANIKO project
September 13, 2017	G. Hadjipavlou: The EU-funded Research Project AGRICYGEN - Launch Event
December 8, 2017	A. Christou, E. Georgiadou, C. Christofi, A. Zissimos, I. Christoforou, G. Papadavid, G. Nicolaou, P. Dalias, D. Neocleous: Integrated management of irrigation water and polluted water bodies, with emphasis in hexavalent chromium pollution. – Day conference



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