Advanced Technologies in Soil Tillage (Ileri Toprak Isleme Teknolojileri)

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Advanced Technologies in Soil Tillage

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Summary

Tillage is defined as manipulating the soil by applying external forces for seedbed preparation, weed control, managing crop residue, mixing fertilizer in the soil, improving soil aeration, alleviating compaction, and optimizing soil temperature and moisture regimes. The tillage systems are classified into two groups: conventional and conservation tillage systems. In conventional tillage systems, soil is inverted and crop residues are buried. Conservation tillage is defined as leaving at least 30% of the crop residue on the field for controlling erosion and conserving the water in the soil. The application of conservation tillage improves the efficient usage of the natural resources of water and soil. However, the conservation tillage methods have some drawbacks. Recently, advanced technologies have been used for conventional soil tillage. These technologies include soil tillage at variable depths throughout the field, according to the variability of soil properties over the field. In this review, some of the research studies that use advanced technologies are given in summary. Most of these technologies are still being studied and have not been introduced into the agricultural practice yet.

Keywords: *Conventional tillage, Conservation tillage, Variable Depth Tillage, Precision Farming*

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Özet

Toprak İşlemede İleri Teknolojiler

Toprak işleme; tohum yatağı hazırlığı, yabancı ot kontrolü, bitkisel artık yönetimi, gübrelerin toprağa karıştırılması, toprağın havalandırılması, toprak sıkışıklığının önlenmesi ve toprak sıcaklığı ve neminin optimizasyonu amacıyla dış kuvvet uygulayarak toprağın işlenmesidir. Toprak işleme sistemleri korumalı ve geleneksel olmak üzere iki grupta sınıflandırılabilir. Geleneksel toprak işleme sistemlerinde toprak alt üst edilerek bitki artıklarının gömülmesi söz konusudur. Korumalı toprak işleme, su ve toprak gibi doğal kaynakların etkin kullanımı gereksiniminden dolayı önemli hale gelmiştir. Korumalı toprak işleme, erozyon kontrolü ve topraktaki suyun muhafazası için bitki artıklarının en az %30'unun toprakta bırakılması olarak tanımlanmaktadır. Ancak korumalı toprak işleme yöntemlerinin bazı dezavantajları da bulunmaktadır. Son yıllarda geleneksel toprak işlemede ileri teknolojiler üzerinde önemli çalışmalar yapılmaktadır. Bu teknolojilerde, toprak özelliklerindeki değişime göre değişken derinlikli toprak işleme yapılmaktadır. Bu yayında ileri teknolojiler kullanılarak yapılan bazı çalışma örnekleri özetlenmiştir. Bu teknolojiler henüz gelişme aşamasında olup tamamen uygulama aşamasına geçmemiştir.

Anahtar Kelimeler: *Geleneksel toprak işleme, Korumalı toprak işleme, Değişken derinlikte toprak işleme, Hassas Uygulamalı Tarım*

1. Introduction

Soil tillage may be defined as making the soil conditions appropriate for plant growth, although there are many different definitions. Tillage practices should avoid the degradation of soil properties and help to create a sustainable environment without a decrease in crop yield. The aims of soil tillage are improving the soil physical conditions for plant growth, mixing organic matter and residues into the soil, eliminating weeds, preparing the seedbed, erosion control, and preparing the soil for irrigation.

In conventional tillage systems, in general, less than 15 percent residue cover is left on the soil after planting (CTIC 2010). Plowing and intensive tillage are performed over the complete field. Primary and secondary conventional tillage operations are normally performed in preparing a seedbed and/or cultivating a given crop. Primary tillage is defined as the tillage operation which constitutes the initial, major soil manipulation operation. In primary tillage, deep tillage practices are applied with disc or moldboard ploughs, chisels, and subsoilers. The shallower tillage practices are applied in secondary tillage operations to pulverize the soil and prepare a fine seedbed for planting with cultivators, disc harrows, rotovators, etc. (SSSA 2010).

Conservation tillage methods are used especially to preserve soil and soil water, and to create a sustainable environment. This system is of great interest as it improves the efficient use of the natural recourses: water, soil, and energy. Conservation tillage is defined as "any tillage or planting system in which at least 30% of the soil surface is covered by plant residue after planting to reduce erosion by water or wind" (CTIC 2010). Though the application of conservation tillage varies from region to region, the major reason for its popularity is its effectiveness for erosion control. In conservation tillage systems, there is no deep soil manipulation that inverts and buries the crop residues. There are five types of conservation tillage systems: no-tillage, mulch tillage, strip (zonal) tillage, ridge tillage, and minimum (reduced) tillage (CTIC 2010). The main principles of the conservation tillage methods are continuous minimum mechanical soil disturbance, permanent organic soil cover, and diversification of crop species grown in sequence or associations (FAO 2010).

Conservation tillage systems have advantages for both soil and water resources. Soil is conserved by eliminating erosion via crop residues and water is conserved by leaving the crop residues on the soil surface so that the water under the soil surface cannot evaporate. Additional positive effects are improvement surface and ground water quality, reduced labor, time and fuel savings, decreased erosion, higher soil moisture, improved water infiltration, decreased soil compaction, more wildlife and biological activity, reduced release of carbon gases, and reduced air pollution (Hill and Mannering 2009).

The conservation tillage has also some disadvantages. The main drawback is its requirement of careful farm management practices. Other disadvantages can be as follows:

- increase of soil pests populations,
- increase of herbicide usage to control weeds competing with the main crops,
- transfer of insect pests and diseases from the crop residues to the next crop,
- uneven distribution and concentration of organic matter in the topsoil,
- more time required until methods result in an excellent soil quality.

Conservation tillage is also not recommended if the soil has compaction problems. Soil compaction restricts the root and crop development resulting in a reduction in yield.

2. Advanced Conventional Tillage Methods

In the advanced conventional tillage methods, soil is tilled based on the variation on the soil conditions and properties. The aims of the advanced tillage methods are to use less fuel and energy and to prevent excessive soil disturbance by varying the tillage applications. Different terms can be used as advanced tillage methods: variable depth tillage, site-specific tillage or precision tillage (part of Precision Agriculture, PA). Using these tillage applications, it is possible to vary the soil tillage depth according to the data from a data source, either a variability map or a real time sensor. Therefore, this method is called Map-Based or Sensor-Based Site Specific Tillage based on the data source. These methods are applied for removing the compacted soil layer at variable tillage depth.

2.1 Map-Based Site Specific Tillage

Soil compaction restricts the root and crop development resulting in a reduction in yield. The compacted region is called as hardpan layer and its location and depth are variable. Soil compaction is eliminated by annual deep tillage, usually to a uniform depth throughout the field. This practice has been shown to improve yields in the soils which are subject to the formation of hardpans; however, there may be a great amount of variability in depth and thickness of hardpan layers. Applying uniform-depth tillage over the entire field may be deeper or shallower than what is needed and it can be costly. Therefore, a technology is needed to determine the tillage depth based on the compacted layer and apply tillage accordingly. This type of variable-depth tillage technology could be beneficial in optimizing the production costs. The map-based site specific tillage requires mapping soil properties before the tillage. In many studies, tillage tools have been used to map the spatial variation of draft force.

McLaughlin and Burtt (2000) collected and mapped data on tillage implement draft, fuel consumption, engine speed, and forward speed in a 30-ha field with an instrumented tractor combined with a combination disk-ripper. They found that the four maps for these parameters were all closely related and showed similar patterns. They also reported that the tillage energy map showed soil variability.

Van Bergeijk et al. (2001) created a drought force map on a 6-ha field using a tractor-plough combination with electronic hitch control sensor, global positioning system (GPS), speed sensor, plough depth sensor, and working width sensor. Specific plough draught varied between 30 and 50 kN m^{-2} in two growing seasons. Clay content was 6-22%. They concluded that the specific plough draught corresponded well with the classical soil survey on clay contents but had a higher spatial resolution. The specific plough draught maps of both years showed a similar pattern. This map enabled reduction of the number of soil samples required to make a sound coverage for a topsoil clay content map.

Wells et. al. (2001; 2005) measured and mapped the spatial distribution of soil compaction as indicated by cone penetrometer resistance (soil cone index, CI) on multiple fields. They measured CI to a depth of 70 cm in increments of 2 cm when the soil moisture content was near field capacity. The 0.4 ha cells of each field were randomly assigned to four tillage treatments: tilled to maximum depth of 40 cm, tilled to the maximum depth for which CI > 1.5 MPa, tilled to a depth of 23 cm, and no till. They found a relationship between crop yield (corn and soybeans) and maximum CI in the tillage zone (40 cm). They concluded that precision tillage produced increased yield relative to compacted cells receiving no deep tillage in five of six crops studied (Wells et al. 2005).

Domsch et al. (2006) used a tractor mounted multi-penetrometer system with four hydraulically driven penetrometer to measure cone index (CI) to a depth of 60 cm at 1-m sampling interval along a 600 m intersect to determine the soil loosening depth to eliminate the compacted layer. They concluded that averaging the CI values of the four penetrometers over 5-m intervals could allow the data be mapped more reliably. They reported that the repeatedly averaged CI readings could be used to derive the loosening depths required to eliminate the soil compaction.

Görücü et al. (2001) used a tractor-mounted penetrometer to map soil compaction and determine the soil tillage depth. An algorithm and computer program was developed to determine the optimum tillage depth to remove the compacted layer (Görücü et al. 2006). They also studied the effects of variable depth tillage on soil physical properties, energy requirements, and plant responses. In addition, they used an electrical conductivity (EC) meter to ascertain the relationships between soil compaction, tillage depth, and soil EC. They applied variable depth and conventional tillage treatments. The conclusions they obtained were: tillage depth can be determined by soil cone penetrometer or EC measurement; approximately 75% of the field studied in 2000 and 67% of the field studied in 2001 required shallower tillage depths (Fig. 1); the energy savings of 56.39% and fuel savings of 33.80% could be achieved by variable-depth tillage; there was a strong correlation between EC readings and cotton yield (r=0.90) and the predicted tillage depths and the soil EC readings (r=-0.83).

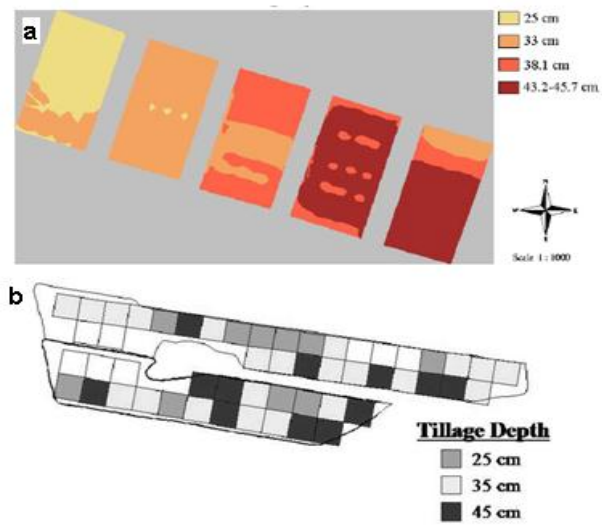

Fig. 1: Map of variability in soil tillage depth (a: Görücü et al. 2001; b: Raper et.al. 2005).

Raper et al. (2005) carried out a similar study by imposing three subsoiling treatments: no-subsoiling (zero-depth subsoiling), site-specific subsoiling (at 25 cm, 35 cm, or 45 cm depth), and deep subsoiling (at 45 cm depth; Fig. 1). They found that site-specific subsoiling resulted in significant savings in draft force and fuel compared to the uniform deep subsoiling at 45 cm depth. Site-specific subsoiling reduced the draft force in 59% in the shallow depth (25 cm) and 35% in the medium depth hardpan plots (35 cm), compared to the uniform deep subsoiling at 45 cm depth. Also, the site-specific subsoiling resulted in 43% and 27% reduced fuel use in the shallow depth and medium depth hardpan plots, respectively, compared to uniform subsoiling at 45 cm depth.

2.2 Sensor-Based Site Specific Tillage

Sensor-based site specific tillage has some advantages over the map-based system. It is faster since the measurement and tillage operations could be performed simultaneously. Also there is no time gap between the data collection and tillage application. In this method, there is no need for an application map as the data collection and variable depth tillage application can be carried out at the same time.

Khalilian et al. (2002) designed an instrumented shank having five load cells to measure mechanical impedance at multiple depths on-the-go (Fig. 2). They measured the soil strength using a cone penetrometer, electrical conductivity meter, and the instrumented shank. They also developed a GPS-based equipment for controlling the tillage depth to match soil physical parameters (Fig. 2). The gage wheels on a four-row subsoiler-bedder were attached to an electro-hydraulic actuator that moved the gage wheels upward or downward to control the tillage depth on-the-go (Fig. 2). They concluded that it was possible to determine the optimum tillage depth using a cone penetrometer, electrical conductivity meter or the instrumented shank.

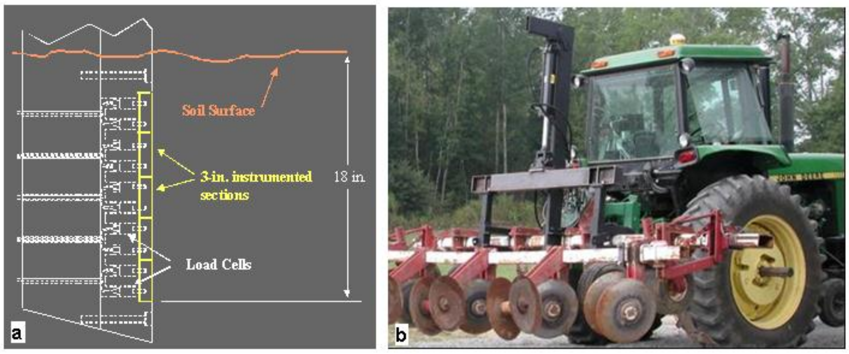

Fig. 2: The instrumented shank (a) and the variable-depth tillage system (b: Khalilian et. al. 2002).

SirJacobs et al. (2002) used a toolbar-mounted octagonal ring transducer to measure horizontal and vertical forces, as well as the torque produced by the shank when pulled through the soil (Fig. 3). They designed a dynamometer and the associated measurement chain to detect local soil strength variations. They established significant relationships between global penetrometry index and the sensor data (R^2=0.81). They concluded that the results show the promising perspective of technological innovations allowing on-line characterization of soil physical state for precision agriculture.

Andrade-Sanchez et al. (2008) developed a soil compaction profile sensor interfaced to a Differential Global Positioning System (DGPS) (Fig. 3). The main features of the sensor were the 90-degree rake angle, reduced shank width of 2.7 cm, and the use of five customized octagonal ring load sensing units, which resulted in a sensing depth of 7.5 to 45.7 cm. The field-ready sensor was to generate continuous soil cutting resistance data in 3D space for enhanced spatial analysis. The data from the sensor was similar to the cone penetrometer data when integrated over a specific soil layer or at a specific depth. They concluded that the device had the potential for developing site-specific tillage maps.

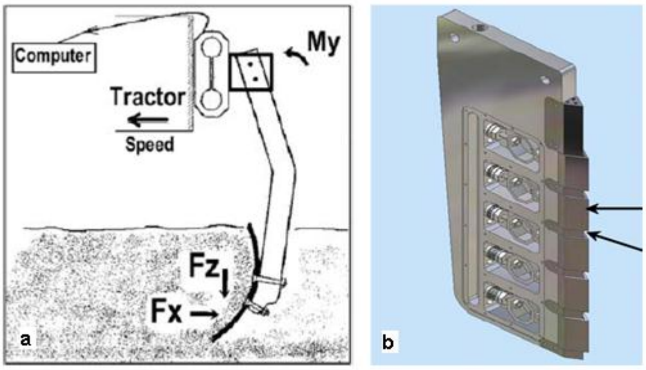

Fig. 3: Soil resistance sensor (a: SirJacobs et al. 2002) and soil profile compaction sensor with five load cells (b: Andrade-Sanchez et al. 2008).

Pitla and Wells (2006) developed an electro-mechanical system with a disc coulter. They evaluated the system by making four passes in the square grid cell and with the aid of hydraulic actuation. The coulter was oscillated between depths of 10 cm and 33 cm as it moved forward. The vertical impedance force given by the soil was recorded continuously. They also collected soil penetrometer data and compared the average coulter indices to average cone indices (r=0.716).

Gilbertson (2001) compared a draft force sensor to a soil conductivity sensor to measure crop yield and soil parameters (clay content, organic matter, pH, and moisture content). Good correlation was found between the data from the sensors and the yield and the soil parameters especially clay content. The soil clay content was more accurately predicted if the data from the two sensors were combined.

Adamchuk et al. (2004) developed a prototype instrumented deep–tillage implement to estimate parameters of linear soil resistance pressure distributions. They reported that the absolute value of soil resistance pressure can be used to determine whether tillage of the particular area was appropriate. Limited field evaluation showed the ability of the system to sense nonlinear vertical distributions of soil mechanical resistance while operating at varying depths. They concluded that additional studies were needed to develop an algorithm for closed-loop control for real-time variable-depth tillage. Adamchuk and Christenson (2007) developed an instrumented blade system for mapping the soil mechanical resistance on-the-go (Fig. 4). They used an array of four strain gages to measure the loads.

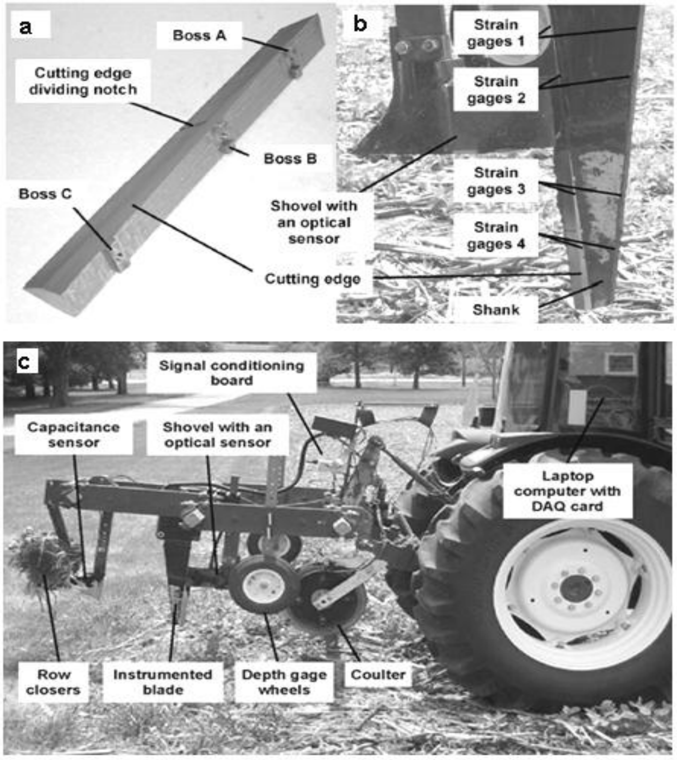

Fig. 4: Instrumented blade system (Adamchuk and Christenson 2007).

3. Conclusions

Conservation tillage has advantages to preserve soil, organic material, and water but may increase pesticide use. In addition, conservation tillage is not recommended if the soil is compacted since soil compaction restricts the root and crop development resulting in yield reduction. On compacted sites, conventional tillage has to be applied. Soil compaction is eliminated by deep tillage, usually to a uniform depth throughout the field. However, there may be a significant variability in depth and thickness of hardpan layers, also, the hardpan may not exist in some parts of the field. It is ideal to determine the soil tillage depth based on the soil parameters and then apply the soil tillage at variable-depth. Map-based and sensor-based variable depth tillage show promising results, including considerable savings on energy and fuel. There are significant numbers of studies on variable depth tillage but most of these technologies are still being studied and have not been introduced into the agricultural practice yet.

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Verband deutsch-türkischer Agrar- und Naturwissenschaftler e. V.
Türk-Alman Tarim ve Tabii Bilim Arastiricilari Dernekleri

Deutsch-Türkische Agrarforschung
Türk-Alman Tarimsal Arastirma

9. Symposium

vom 22. März bis 26. März 2010
an der
Mustafa Kemal-Universität Antakya-Hatay

9. Sempozyumu

22. 03. 2010 - 26. 03. 2010
Mustafa Kemal-Universität Antakya-Hatay

Redaktion:
Dr. Martin Kücke und Prof. Dr. Bernd Honermeier

VVB LAUFERSWEILER VERLAG

Inhalt – Icindekiler

5. Pflanzenbau und ökologischer Landbau

6. Pflanzenzüchtung und Phytopathologie

7. Agrartechnik und Futterbau

8. Biometrie und Versuchswesen

9. Tierzucht und Tierhaltung

10. Veterinärmedizin

Vorwort

Im vorliegenden Tagungsband werden die wissenschaftlichen Beiträge zusammengefasst, die auf dem 9. Symposium des Verbandes der deutsch-türkischen Agrar- und Naturwissenschaftler an der Mustafa Kemal-Universität Antakya vorgestellt wurden. Die Tagung wurde inhaltlich sowohl von Mitgliedern und Wissenschaftlern der türkischen Sektion als auch von Mitgliedern der deutschen Sektion getragen. Die Vorträge wurden in deutscher oder in englischer Sprache gehalten. Im vorliegenden Band wird zu jedem Beitrag eine englisch-sprachige Zusammenfassung vorangestellt.

Während des Symposiums wurden sowohl Übersichtsbeiträge gehalten als auch konkrete Ergebnisse aus laufenden Forschungsvorhaben präsentiert. Die Themen wurden nicht auf ein bestimmtes Leitthema ausgerichtet, sondern waren sehr vielfältig und erstreckten sich auf verschiedene Disziplinen der Agrarwissenschaften und der Veterinärmedizin. Schwerpunktmäßig wurden Arbeiten aus der Bodenkunde, dem Pflanzenbau, der Ökonomie und Agrarpolitik sowie der Tierzucht und Tierhaltung vorgestellt. Daneben waren auch Umweltthemen sowie die Auswirkungen des Klimawandels Gegenstand einiger Vorträge. Auch methodische Beiträge aus der Biometrie haben das Symposium bereichert.

Während des dreitägigen Symposiums wurden von der türkischen Sektion 45 und von der deutschen Sektion 23 Vorträge gehalten und diskutiert. Ein Drittel der Beiträge basierte auf Ergebnissen der Zusammenarbeit zwischen Wissenschaftlern aus beiden Sektionen. Zum Abschluss des 9. Symposiums wurde eine interessante zwei-tägige Fachexkursion durchgeführt, die auch mit einem schönen Kulturprogramm gekoppelt war.

Das Symposium wurde durch die finanzielle Unterstützung der TÜBITAK (The Scientific and Technical Research Council of Turkey) und der DFG (Deutsche Forschungsgemeinschaft) ermöglicht. Für diese Unterstützung bedankt sich der Vorstand des Verbandes der deutsch-türkischen Agrar- und Naturwissenschaftler (VDTAN) sehr herzlich.

Ein großer Dank gilt auch den Organisatoren der türkischen Sektion des VDTAN (Prof. Dr. Mehmet Bülbül) und den Kollegen von der Mustafa-Kemal-Universität in Antakya, insbesondere dem Rektor, Herrn Prof. Dr. Şerefettin Canda. Sie haben die Tagung mit viel Engagement vorbereitet und alle Gäste mit großer Gastfreundschaft empfangen. Unser Dank gilt auch den Mitgliedern der Deutschen Sektion des VDTAN (Prof. Dr. Franz Josef Bockisch, Dr. Martin Kücke und Mitarbeitern), die an der Organisation der Tagung und an der Herausgabe dieses Bandes beteiligt waren.

Gießen und Ankara, im Juni 2016

Prof. Dr. Bernd Honermeier	Prof. Dr. Mehmet Bülbül
Deutsche Sektion	Türkische Sektion
Vorsitzender	Vorsitzender

ÖNSÖZ

Türk Alman Tarım ve Tabii Bilim Araştırıcıları tarafından Antakya'da Mustafa Kemal Üniversitesinde 23 - 27. Mart 2010 tarihinde düzenlenen 9. Uluslararası Sempozyumda sunulan bildiriler, bu kitapta bir araya getirilmiştir.Sempozyum içerik itibariyle Türk ve Alman seksiyonlarının bilim insanları ve üyeleri tarafından birlikte hazırlanmıştır. Bildiriler almanca veya ingilizce olarak sunulmuştur.Bütün bildirilerin ingilizce özetine bu kitapta yer verilmiştir.

Sempozyum süresince bir taraftan tamamlanmış bildiriler sunulurken, diğer taraftan da yürütülmekte olan araştırmaların kesinleşmiş sonuçları dile getirilmiştir. Seçilen bildiriler, belirli bir konuya odaklanmamış olup,geniş açılı bir yaklaşımla, Tarım ve Veteriner bilimlerinin çok çeşitli disiplinlerini kapsamışlardır.Sempozyumda, Toprak Bilimi, Bitki Yetiştirme, Ekonomi ve Tarım Politikası, Hayvan Islahı ve Hayvan Yetiştiriciliği konuları ağırlıklı olarak incelenmiştir.Bunların yanı sıra ayrıca Çevre konularını ve İklim Değişikliğinin Etkilerine ilişkin bildiriler de sunulmuştur. Biometri alanında sunulan metod içerikli bildiriler sempozyuma zenginlik katmıştır.

Üç gün devam eden sempozyum süresince Derneğin (VDTAN) Türkiye Seksiyonu katılımcılarınca 45, Almanya Seksiyonu katılıcılarınca 23 bildiri sunulmuş ve detaylı bir şekilde tartışılmıştır.Sunulan bildirilerin üçte biri iki Seksiyonun bilim insanlarının birlikte yaptıkları araştırmalardır. 9.Sempozyum mesleki ve kültürel içerikli olarak düzenlenen, iki günlük gezi ile tamamlanmıştır.

Bu sempozyum, TUBİTAK (Türkiye Bilimsel ve Teknik Araştırma Kurumu) ve Alman Bilimsel Araştırma Kurumu'nun (DFG, Deutsche Forschungsgemeinschaft) Finansman destekleri ile gerçekleştirilmiştir. Bu desteklerinden dolayı Türk-Alman Tarım ve Tabii Bilim Araştırıcıları Derneği (VDTAN) olarak candan teşekkürlerimizi sunarız.

Sempozyumu büyük bir gayret ve özveri ile düzenleyen, katılımcıları güzel bir misafirperverlikle ağırlayan, Türk-Alman Tarım ve Tabii Bilim Araştırıcıları Derneği'nin (VDTAN) Türkiye seksiyonu organizatörlerine (Prof. Dr. Mehmet Bülbül) ve Mustafa Kemal Üniversitesindeki meslektaşlarımıza ve özellikle de Üniversitenin Rektörü Sayın Prof. Dr. Şerefettin Canda'ya çok teşekkür ederiz.

Ayrıca VDTAN'nın Almanya Seksiyonu üyelerine (Prof. Dr. Franz-Josef Bockisch, Dr. Martin Kücke ve mesai arkadaşlarına) sempozyumun düzenlenmesindeki ve sempozyum kitabının basıma hazırlanmasındaki katkıları için teşekkür ederiz.

Ankara ve Giessen, Haziran 2016

Prof. Dr. Bernd Honermeier
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