Machine Translation of Arabic Interrogative Sentence into English

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Abstract

The present work reports our attempt in developing a bi-lingual Machine Translation (MT) tool in the agriculture domain. The work described here is part of an ongoing research to automate the translation of user interfaces of knowledge-based systems. In particular, we describe the translation of Arabic interrogative sentence into English. In Central Laboratory for Agricultural Expert Systems (CLAES), this tool is found to be essential in developing bilingual (Arabic-to-English) expert systems because both the Arabic and the English versions are needed for development and usage purpose. The tool follows the transfer-based MT approach. A major design goal of this tool is that it can be used as a stand-alone tool and can be very well integrated with a general MT system for Arabic sentence. The paper also describes our experience with the developed MT system and reports results of its application on interrogatives from real agricultural expert systems.

1. Introduction

Machine translation (MT) is the area of information technology and applied linguistics dealing with the translation of human languages such as English and Arabic. With globalisation and expanding trade, demand for translation is set to grow. Computer technology has been applied in technical translation in order to improve one or both of the following factors (Trujillo, 1999):
Speed: Translation by or with the aid of machines can be faster than manual translation.
Cost: Computer aids to translation can reduce the cost per word of a translation.

In addition, the use of MT can result in improvements in **quality**, particularly in the use of consistent terminology within a text or for a particular kind of client. Similarly, the **availability** of MT makes it ideal for translation of Web pages and other materials on the internet.

Translation of Arabic sentences is a difficult task. The difficulty comes from several sources. One is that sentences are long. The average length of a sentence is 20 to 30 words, and it often exceeds 100 words. Another difficulty comes from the sentence structure. The Arabic sentence is complex and syntactically ambiguous due to the frequent usage of grammatical relations, order of words and phrases, conjunctions, and other constructions. Consequently, most of the researches in Arabic MT mainly concentrated on the translation from English to Arabic. An interesting study by (Rafea et al., 1992) is the English to Arabic translator that translates sentences from the political news of the middle east. A study of translating English noun phrases to Arabic is presented in (Mohamed, 2000). This study shows the possibility of translating titles of theses and journals from the computer science domain. The translation of an English subset of a knowledge base is described in (El-Saka et al., 1999). This tool translates English phrases extracted from the knowledge base that was written in KROL (Shaalan et al., 1998) to the corresponding Arabic phrases. On the contrary, little work has been done in developing Arabic to English MT system. The big gab between Arabic and English in both lexical and syntactic aspects causes difficulties of building these systems. The lexical gab between Arabic and English is studied in (Al barhamtoshy, 1995). The syntactic gab is studied in (Farouk, 1999).

The present work addresses the translation of the Arabic interrogative sentence into English for automating the translation of user interfaces. This includes also the (imperative) form of the verbal sentence that is commonly used for interrogating users of nowadays computer applications. The proposed MT tool described here is part of an ongoing research to automate the translation of user interfaces of knowledge-based systems. In Central Laboratory for Agricultural Expert Systems (CLAES), this tool is found to be essential in developing bilingual (Arabic-to-English) expert systems because both the Arabic and the English versions are needed for development and usage purpose.

The next section outlines the overall architecture of the proposed Arabic to English MT system. The following sections describe the main components of the system. In a concluding section, we discuss its application on interrogatives from real agricultural expert systems and present some final remarks.

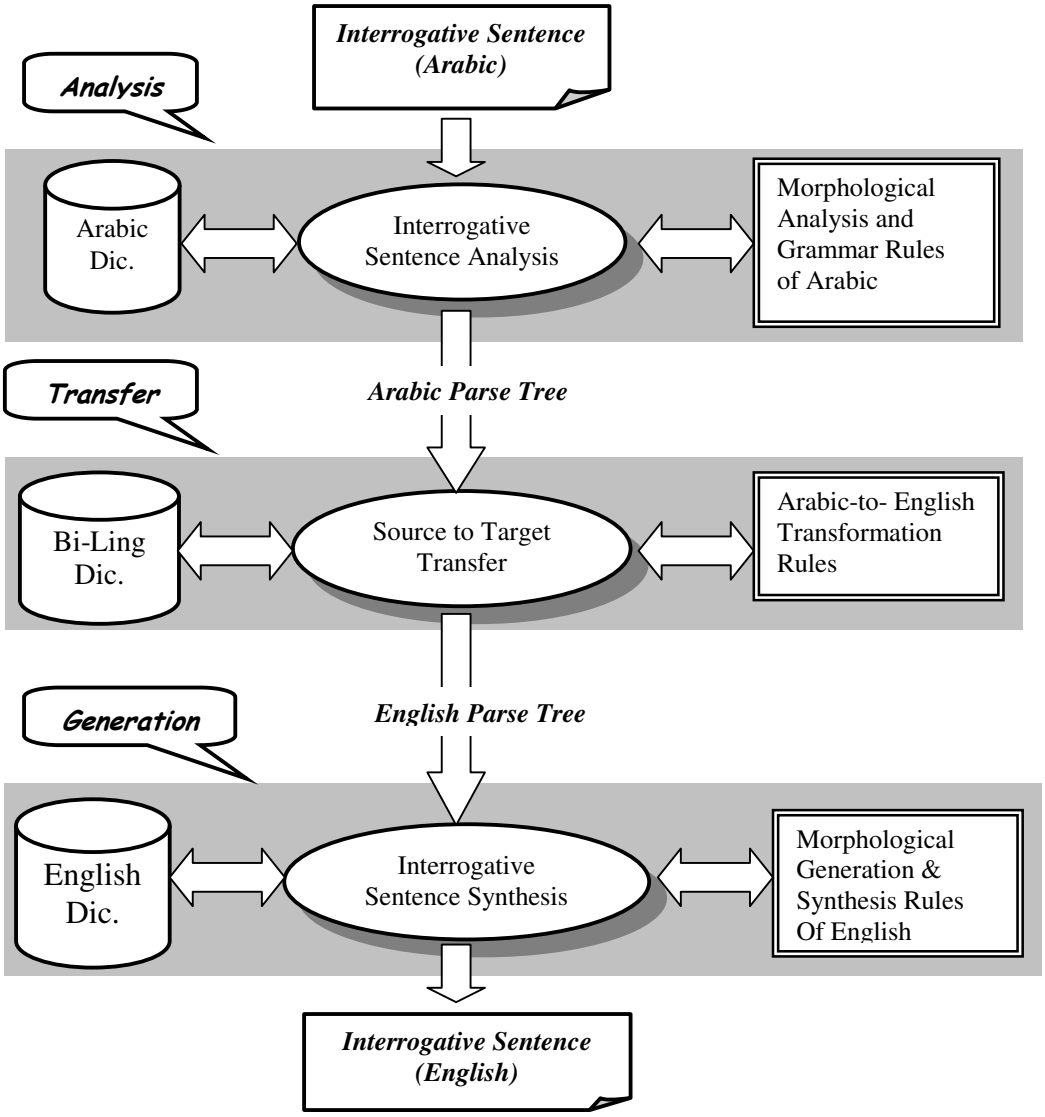

Fig 1. Overall Structure of Arabic-to- English Interrogative sentence Translator

2. Overall Structure of the System

There are three basic approaches being used for developing MT systems that differ in their complexity and sophistication. These approaches are: direct approach, transfer-based approach, and interlingua approach. The current work follows the transfer-based MT approach. There are many factors which make transfer an attractive design for MT (Trujillo, 1999):

1. Many systems are bilingual, or their principal use is for translation in one direction between a limited number of languages.
2. Where full multilinguality is required, it is possible to have a hub language into and out of which all translation is done.
3. Portions of transfer modules can be shared when closely related languages are involved. For example, an English-Portuguese module may share several transformations with an English-Spanish module.

The architecture of the transfer-based Arabic to English MT system is given in Fig. 1. In this overview of the architecture, the arrows indicate the flow of information. Ovals are modules of the system. Rectangles are the linguistic knowledge. The proposed system is based on the transfer approach, with

three main components: an analyzer, a transfer component, and a generation component. The following summarizes the translation process:

1. The morphological analyzer provides information about inflectional features as well as the stem-form of an inflected Arabic word.
2. The syntactic parser builds a syntactic dependency tree, which represents meaningful linguistic relationships between constituents of an interrogative sentence.
3. The Lexical transfer will map Arabic lexical units to their English equivalent. It will also map Arabic morphological features to the corresponding set of English features.
4. The Syntactic transfer will map the Arabic dependency tree to the equivalent English syntactic structure.
5. The morphological generator synthesizes the inflected English word in its right form based on the morphological features.
6. The syntactic generator is responsible for polishing and producing the surface structure of the English interrogative sentence. Then, the final tree is traversed to produce the translation output.

Prolog is one of the most widely used programming languages in computational linguistics (Shaalan, 1998). We have chosen Prolog as the implementation language of our translation tool. Among the features that make it attractive are its efficient unification, its declarative nature and its backtracking regime. The tool is implemented in SICStus Prolog and the parser is written in definite clause grammar (DCG) formalism. DCG translate grammar rules directly to Prolog, producing a simple top-down parser.

3. Syntax Analysis

The syntax analysis component assigns grammatical structures to the input interrogative sentences by means of Arabic grammatical rules. In order to perform the syntax analyzer, a DCG describing the structure of the interrogative in agricultural expert systems, was implemented. This was done by examining large number of interrogative sentences in agricultural expert systems at CLAES. Fig. 2 shows an implementation of DCG of the Arabic interrogative sentence

```
interrogation(interrogation(Interr,NP))  -->  interrogative(Interr),np(NP).
interrogation(interrogation(Interr,VP))  -->  interrogative(Interr),vp(VP).
interrogation(interrogation(Interr,NP,VP))  -->  nterrogative(Interr),np(NP),vp(VP).
interrogation(interrogation(Interr,Pron,NP))  --> interrogative(Interr),separate_pronoun(Pron), np(NP).
interrogation(VP)  -->  vp(VP).
vp(vp(V,NP))  -->  verb(V),np(NP).
vp(vp(V)) -->  verb(V).
np(Quasi_proposition) -->  quasi_proposition(Quasi_proposition),!.
np(np('(',NP,')')) -->  ['('],np(NP),[')'].
np(np(N,NP)) -->  noun(N),np(NP).
np(np(Adj,NP)) -->  adj(Adj),np(NP).
np(np(N)) -->  noun(N).
np(np(Adj)) -->  adj(Adj).
np(np(AdV,NP)) -->  adverb(AdV),np(NP).
np(np(Pron,NP)) -->  pronoun(Pron),np(NP).
np(np(Pron,VP)) -->  pronoun(Pron),vp(VP).
np(np(Conj,NP)) -->  conj(Conj),np(NP).
np(np(num(Num),NP)) -->  [Num],np(NP),{number(Num)}.
quasi_proposition(quasi_proposition(Prep,NP)) -->  preposition(Prep),np(NP).
quasi_proposition(quasi_proposition(Prep,VP)) -->  preposition(Prep),vp(VP).
```

Fig. 2 A DCG for the Arabic interrogative sentence

In order to implement the parser, it was needed to perform morphological analysis on the inflected Arabic words. An Arabic monolingual dictionary was also needed to successfully implement the morphological analyzer.

In a previous work (Rafea et al., 1993), we analyzed and discussed the problem of implementing a morphological analyzer for inflected Arabic words. With respect to the implementation of the Arabic parser, we took the advantage of the already developed morphological analyzer by integrating it with

the Arabic parser. The morphological analyzer returns to the parser the words in its primitive form with some additional information such as tense of a verb and number of a noun.
Entries of the Arabic dictionary can be interrogatives, pronouns, prepositions, adverbs, conjunctions, verbs, adjectives, and nouns. Considering verbs, the verb is stored in the dictionary in its singular past tense. Considering nouns and adjectives, they are stored in the dictionary in their singular masculine form. In addition, the Arabic dictionary also includes entries for compound forms, usually for technical terms, and irregular nouns.

Fig. 3 shows the parse tree of the simple sentence "مـــا حالـــة نظـــام الصرف" that would produce from the Arabic parser. The leaves of the tree are the stem forms along with their morphological features.

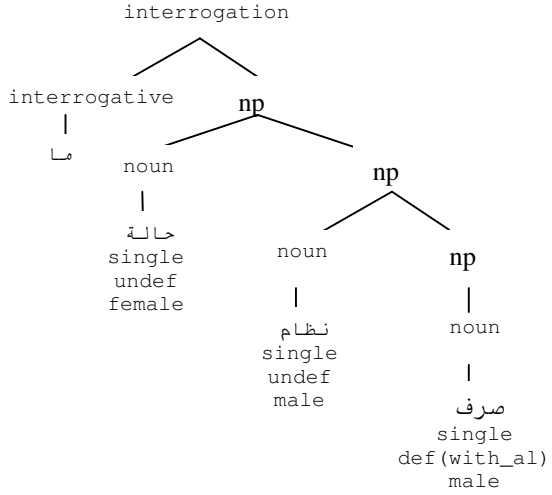

Fig 3. A parse tree for a simple sentence

4. Syntactic Transfer MT

Syntactic transfer systems rely on mappings between the surface structure of sentences: a collection of tree-to-tree transformations is applied recursively to the analysis tree of the source language in order to construct a target language analysis tree (Arnold, 1993 & Arnold et al., 1994). Fig. 4 shows an implementation example of transfer rules for an Arabic interrogative sentence headed by 'ما'. The tree-to-tree transformation algorithm is a recursive, non-deterministic, top-down process in which one side of the tree-to-tree transfer rules is matched against the input structure, resulting in the structure on the right-hand-side. As a simple example, consider the Arabic parse tree shown in Fig. 3, the tree-to-tree transformation would result in the two English trees shown in Fig. 5.

```
% 'ما' NP <==> what to-be NP
transfer(interrogation(IA,NPA),interrogation(IE,VPE)):-
       ( IA=interrogative('ما'); … /* other similar interrogatives */),
       NPA=np(noun(_,single,_,_,_),_),
       VPE=vp(verb(is,present,trans),NPE),
       transfer_word(IA,IE), /* lexical transfer */
       transfer_np(NPA,NPE). /* transfer of NP is to take place */
% 'ما' N NP <==> what to-be N of NP
transfer(interrogation(IA,NPA),interrogation(IE,VPE)):-
       ( IA=interrogative('ما'); … /* other similar interrogatives */),
       NPA=np(NA,NPA1),
       (NPA1=np(noun(_,_,_,_,_),_)
       ; NPA1=np(noun(_,_,_,_,_))),
       NA=noun(_,single,_,_,_),!,
       VPE=vp(verb(is,present,trans),
            np(NE,preposition_phrase(preposition(of),NPE))),
       transfer_word(IA,IE),  /* lexical transfer */
       transfer_word(NA,NE),  /* lexical transfer */
       transfer_np(NPA1,NPE). /* transfer of NP is to take place */
```

Fig. 4 An implementation example of transfer rules

Just as the analysis component has a dictionary so also the transfer component has a bilingual dictionary. This dictionary relates the primitive form of the Arabic lexical units to the primitive form of the English lexical units. This leads to mapping the Arabic verb to its corresponding singular present tense, as it is the primitive form of the English verb. This will result in shifting a lot of the workload for synthesizing the right verb form to the transfer component. The mapping of features is straightforward. However, irrelevant features such as the gender of a noun/subject that are not needed in the translation to English are not carried over from the source tree to the target tree.

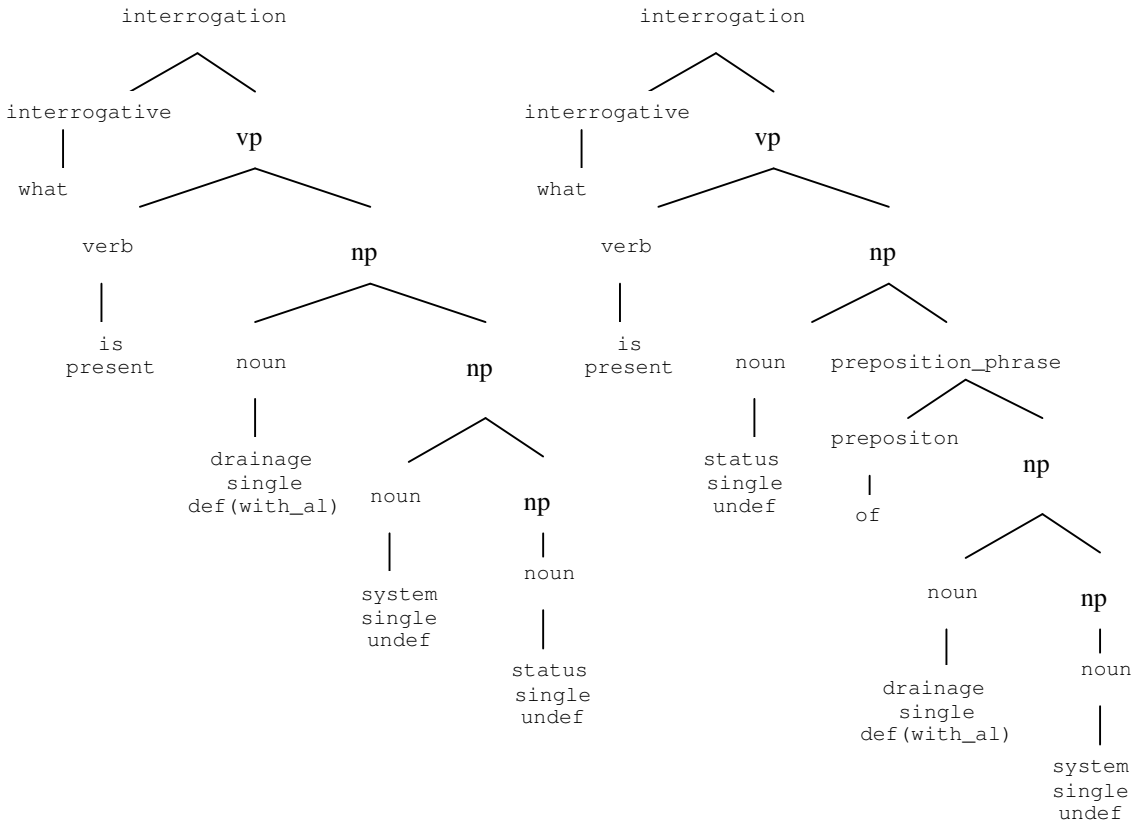

Fig. 5 A tree-to-tree transfer Example

In our interrogative sentence translator, the actual translation occurs in the transfer phase. The following paragraphs describe the problems encountered while designing this phase. These problems are regarded as peculiar to translation, since they arise from the divergences and mismatches between source and target sentences.

NON-DETERMINISM

In general, several different transfer rules will be able to apply to a structure, giving alternative (not necessarily correct) translations. For example the translation of the sentence

أين موضع المظهر غير الطبيعي على الأوراق

would produce the following acceptable sentences.

```
where is abnormal appearance position on leaf
where is position of abnormal appearance on leaf
```

The user is able to choose between the two translations because both have the same meaning. They are provided in order to meet the different styles of English sentences that are desirable

On the contrary, alternative translations may be inevitable because the translation rules produce correct target structure in some circumstances while they produce non-acceptable-grammatically incorrect-translations in the others. This is best clarified by the following two examples.

هل تريد انتاج مبكر
do you want early production
does production want early

هل تهب الرياح عادة فى هذا المكان
do you bellow usually wind in this location
does wind bellow usually in this location

In the first example, the first translation is the correct one because the verb ("تـــريـد") has a morphological features that indicates a second person. Hence, the pronoun (you) is produced in the translated sentence. However, this is not applicable in the second example where its second translation is acceptable.

WORD OMISSION

The translation of Arabic to English is different because some words have been omitted. In some circumstances, the pronoun that follows the interrogative can be omitted. For example, the translation of the sentence

ما هى حالة نظام الصرف

is

what is drainage system status

The pronoun "هى" is omitted without affecting the sentence meaning.

As another example, consider the translation of the sentence

هل قمت بتحليل الفطر

to

did you do fungal analysis

Owing to the lexical gab between Arabic and English, the preposition "ب" is omitted from the translation although its role in the sentence is not optional.

WORD REPLACEMENT

The translation of Arabic to English is different because words are mapped to different syntactic categories. For example, the translation of the sentence

ما نوع الأوراق التى لها مظهر غير طبيعى

is

what is type of leaf which has abnormal appearance

Owing to the lexical gab between Arabic and English, the preposition ('ل') is translated to another category, which is the verb ('has').

CONTEXT DEPENDENCY

An interrogative may be translated according to the word that follows it. For example, the interrogative "هـــل" has different translation according to the noun or the verb that follows. The following three examples shows these divergences.

هل تستطيع غلق نقاطات النباتات غير الموجودة
can you close absent plant dripper

هل هناك أى نمو غير طبيعي
is there any abnormal growth

هل تريد أن تقترح فترات الرى
do you want to suggest irrigation interval

The verbs can, to-be, and to-do, respectively, are translated as a syntactic head of the target English sentence according to the word that follows "هل".

WORD ORDER

To get the right translation order of Arabic noun phrase into its corresponding English noun phrase, the right-left order of nouns and adjective are reversed. For, example translation of the sentence

اختر السماد المفضل لعنصر البوتاسيوم

is:

select preferable fertilizer for potassium element

The noun phrase "السماد المفضل", which is a noun followed by an adjective, is translated to "preferable fertilizer ", where the adjective follows the noun. Similarly, the embedded noun phrase "عنصر البوتاسيوم" is translated to "potassium element" by reversing the order of its constituting nouns.

5. Syntactic Generation

This is the last phase in the translation process. The generation component, include morphological generation of English words and a tree-to-tree transformation for syntactic discrepancies not accounted for during transfer. Fig. 6 shows an implementation example of generation rules of an English interrogative sentence. The generated syntactic tree is traversed in a depth-first manner to produce the surface English interrogative sentence.

```
% Prep def N -> prep the def N
synthesize(preposition_phrase(P,np(W)),
 preposition_phrase(P,np(det(the),np(W1)))):-
       W=noun(N,Number,Definition),
       Definition=def(with_al),!,
       synthesize_plural(N,Number,N1),
       W1=noun(N1,Number).
% def noun NP -> the noun NP
synthesize(np(W,NP),np(W1,NP1)):-
       NP=np('(',_,')'),
       W=noun(N,Number,_Definition),!,
       synthesize_plural(N,Number,N1),
       W1=noun(N1,Number),
       copy_to_preposition_phrase(NP,NP1).
```

Fig. 6 An implementation example of generation rules

The morphological generation module is responsible for synthesizing the English words in its right form. The input to this module is the origin of the English words, which is passed by transfer phase with some information about each word. The output is the English word in its right form. This module synthesizes right tense of verbs and the right number of nouns. This process includes an English monolingual dictionary, which stores nouns in their singular form and verbs in their singular present tense.

The main problem encountered while designing the syntactic generation module is the generation of the article, "the". This leads to restructuring the English noun phrase subtree in order to put it in its right

form. Another problem is the synthesis of passive voices. These problems are illustrated by the following example.

Input: اختر واحدا من الأسمدة العضوية التالية لكى يستخدم
Transfer: `select one from following organic manure to use`
Output: `select one from the following organic manure to be used`

6. Results and Conclusion

This paper has been concentrated on issues in the design and implementation of a transfer-based MT system, which translates an Arabic interrogative sentence into English. A major design goal of this tool is that it can be used as a stand-alone tool and can be very well integrated with a general MT for Arabic sentence.

The MT as described here was tested using different texts from different agriculture expert systems at CLAES. It has demonstrated its capability to get almost all possible translations of an Arabic interrogative sentence (see the Appendix). From what this tool provides, we can say it has achieved its main objective. The system consists of 20 DCG rules, 20 transfer rules, and 8 generation rules for the three-phase translation. The system consists of 1012 Prolog lines and was implemented on Pentium II computer using SICStus Prolog.

Considering the test results, the system has proven to be successful in getting a very good quality of translation. Quality stands for the correctness and style of the English sentence produced by the translation process. In testing the translation function, 50 sentences were entered and their correct translations were received. The non-deterministic feature of the tool fills the syntactic gab between the Arabic and English sentences and allows for different translation styles.

Future work will introduce a cooperative mechanism among the various kinds of framework, such as example-based, rule-based, and statistically-based into the interrogative MT tool.

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Appendix: Output from the interrogative MT.

ما هو نوع التربة
what is the soil type
what is the type of soil
ما هو تاريخ الشتل
what is the date of transplantation
what is the transplantation date
ما هى حالة نظام الصرف
what is the drainage system status
what is the status of the drainage system
ما تاريخ المبيد الأخير
what is the last pesticide date
what is the date of the last pesticide
ما اسم المادة الأخيرة
what is the last material name
what is the name of the last material
هل قمت بتحليل كائن التربة
did you do with the soil organism analysis
did you do the analysis of the soil organism
did you do the soil organism analysis
ما عدد النباتات المصابة بالنيماتودا
what is the infected plants number with the nematode
what is the number of the infected plants with the nematode
ما عدد النباتات المصابة بفطر التربة
what is the infected plants number with the soil fungal
what is the number of the infected plants with the soil fungal
ما أعداد كائن فطر التربة
what are the numbers of the soil fungal organism
what are the soil fungal organism numbers
هل تريد أن تقترح فترات الرى
do you want to suggest the irrigation intervals
هل تريد انتاج مبكر
do you want early production
does production want early
ما هى حالة النبات المصاب
what is the infected plant status
what is the status of the infected plant
ما هو مظهر الأوراق
what is the appearance of leaves
what is the leaves appearance
ما لون الأوراق غير الطبيعية فى الصوبة
what is the abnormal leaves color in the tunnel
what is the color of the abnormal leaves in the tunnel

ما مظهر الأوراق غير الطبيعية فى الصوبة
what is the abnormal leaves appearance in the tunnel
what is the appearance of the abnormal leaves in the tunnel
أين موضع المظهر غير الطبيعي على الأوراق
where is the abnormal appearance position on the leaves
where is the position of the abnormal appearance on the leaves
هل قمت بتحليل الفطر
did you do with the fungal analysis
did you do the analysis of fungal
did you do the fungal analysis
هل قمت بتحليل النيماتودا
did you do with the nematode analysis
did you do the analysis of nematode
did you do the nematode analysis
ما حالة النيماتودا فى الموسم الأخير
what is the nematode status in the last season
what is the status of the nematode in the last season
ما حالة كائن فطر التربة
what is the soil fungal organism status
what is the status of the soil fungal organism
ما حالة إصابة الفطر فى الموسم الأخير
what is the fungal infection status in the last season
what is the status of the fungal infection in the last season
ما حالة كائن نيماتودا التربة
what is the soil nematode organism status
what is the status of the soil nematode organism
ما نوع نيماتودا التربة
what is the soil nematode type
what is the type of the soil nematode
كم عدد مرات الرى (فى كل يوم)
how many irrigation times (per day)
how many times of irrigation (per day)
هل دهنت الغطاء البلاستيكى بسبيداج
did you paint the plastic cover with sepdage
هل لاحظت أى إصابة نيماتودا في الموسم الأخير
did you notice any nematode infection in the last season
did you notice infection of nematode in the last season
did you notice nematode infection in the last season
ما مستوى النيتروجين فى سطح التربة
what is the level of the nitrogen in the soil surface
what is the nitrogen level in the soil surface
ما مستوى البوتاسيوم فى سطح التربة
what is the level of the potassium in the soil surface
what is the potassium level in the soil surface
ما مستوى الماغنسيوم فى سطح التربة
what is the level of the magnesium in the soil surface
what is the magnesium level in the soil surface
ما مصدر المياه
what is the source of waters
what is the waters source
هل تستطيع غلق نقاطات النباتات غير الموجودة
can you close the absent plants drippers
هل هناك نسبة غير متزنة بين النمو الخضرى و الزهرى
is there imbalance ratio between the flowery and vegetative growth
ما مستوى الفوسفور فى سطح التربة
what is the level of the phosphorus in the soil surface
what is the phosphorus level in the soil surface
ما حالة النقاطات التى لا تلازم النباتات
what is the drippers status which does not correspond to plants

what is the status of the drippers which does not correspond to plants

اختر واحدا من الأسمدة العضوية التالية لكى يستخدم

select one from the following organic manure to be used

اختر نوع العناصر الصغرى لكى يستخدم

select the micro elements type to be used

ما الطريقة المفضلة لتعقيم التربة

what is the preferable method for the soil sterilization

ما عرض الصوبة (بالمتر)

what is the tunnel width (in meter)

what is the width of tunnel (in meter)

هل تهب الرياح عادة فى هذا المكان

do you bellow usually the wind in this location

does the wind bellow usually in this location

ما نسبة كربونات الكالسيوم فى التربة

what is the calcium carbonate ratio in the soil

what is the ratio of the calcium carbonate in the soil

ما طول الصوبة (بالمتر)

what is the length of tunnel (in meter)

what is the tunnel length (in meter)

كم كمية سماد عضوى أضفتها (بالمتر المكعب)

how much organic manure did you add (in cubic meter)

كم عدد النقاطات (فى كل 1000 متر مربع)

how many drippers (per 1000 square meter)

اختر السماد المفضل لعنصر البوتاسيوم

select the preferable fertilizer for the potassium element

ما وحدة التسميد المفضل

what is the preferable nutrient unit

what is the unit of the preferable nutrient

هل هناك أى نمو غير طبيعي

is there any abnormal growth

هل هناك أى مسارات أنفاق على التربة

is there any galleries on the soil

هل رششت مبيد فى الأيام القليلة الماضية

did you spray pesticide in the last few days

ما المتوسط النسبي للرطوبة فى الأيام القليلة الماضية

what is the relative average for the humidity in the last few days

ما متوسط درجة الحرارة فى الأيام القليلة الماضية

what is the average of the temperature in the last few days

what is the temperature average in the last few days