Archives of Agriculture Sciences Journal
Print ISSN: 2535-1680
Online ISSN: 2535-1699

ARCHIVES OF AGRICULTURE SCIENCES JOURNAL
Volume 4, Issue 3, 2021, Pages 132–143
Available online at www.agricuta.edu.eg
DOI: https://dx.doi.org/10.21608/aasj.2021.226445

Expert system to select a proper chemigation-injection system according to field condition

El Lithy A. M.*, Elglaly A. M. M.

Faculty of Agricultural Engineering, Al-Azhar University, Assiut 71524, Egypt

Abstract

The aim of this research is to help in selecting an appropriate chemical injector in certain situations. Systems under investigation included: (1) Bypass pressure differential tank, (2) Piston injection pump, (3) With suction pipe of irrigation pump, (4) Diaphragm injection pump, (5) Separate electric centrifugal pump, (6) Venturi, and (7) Independent power injection unit developed by Lithy (2012). Evaluation of systems for selection depend on farm resources and conditions (water source, power source, labor, system pump capacity, distance from pump to field, irrigation time, irrigation system, operating pressure, required injection rate, initial cost, area, safety consideration). Results of expert system (ES) approach were validated through consulting with domain expert and references. Each chemical injector type was given a score for every resource item. The highest summation for any system, indicate its suitability for the set of conditions composed. Four actual trial cases were put under validation: Namely case (A), (B), (C), and (D). Results corroborated that using of a separate electric centrifugal pump was the most appropriate choice, with score weight of 13.25 which is about 43% above the average of all the choices in case (A), for big scale farm with electric power supply, well water source, and unlimited irrigating time. Whereas, for cases (B) and (C) the most appropriate proved to be the independent power injection unit developed by Lithy (2012) with score 14.5 and marginal advantages over other systems due to unavailable power source, limited irrigation time and high rate of chemical injection required. The choice with suction pipe of irrigation pump recorded the highest score weight of 15.25 which is about 37% above the average of all the choices in case (D) with condition of underground water reservoir and unlimited irrigation time. In conclusion the expert system proposed is valid in different cases including extreme representative situations.

Keywords: expert system, chemical injector, irrigation, chimigation, field conditions.

*Corresponding author: El Lithy A. M.,
E-mail address amaher70@azhar.edu.eg

Copyright © 2021
(cc) BY-NC

1. Introduction

Selection of proper chemical injection technique in pressurized irrigation systems is the farmer/ engineer key to higher yields and healthier crops. Also, the choice of suitable fertilizers is also very important and based on several factors like nutrient form, purity, solubility, and cost. It is very important to select a fertilizer injection method that best suits irrigation system and crop to be grown Whereas each fertilizer or chemical injector is designed for a specific pressure and flow range. So, care must be taken in selecting a fertigation system that suits farm condition and requirement. Caleder and Bert (2007), Awady *et al*. (1997; 2002; 2003; 2006), Hassan and Sharaf (1997), Awady (2016), El Diba (2017), Bedair (2018), and El-Sahn (2021) showed that expert system approach can be efficiently used as a base selection for an appropriate system among choices in different situations for machinery, irrigation and agricultural practices / management. Janos (1995) stated that to inject the fertilizer solution into the irrigation system, four different fertigators can be used: venturi pump, by-pass flow tank, pressure differential system or injection pump. The general advantages of the injection pump system are the high degree of control of dosage and timing of chemical application, centralized and sophisticated control, portability, no serious head loss in the system, labor-saving and relatively cheap in operation. With this method, the solution is normally pumped from an open unpressurized tank, and the choice of type of pump used is dependent on the power source. The pump may be driven by water flow, by an internal combustion engine, by an electric motor or by a tractor power take-off. Kranz *et al*. (1996) found that chemical injection devices (piston, diaphragm, and venturi type injection) with the same model number do not deliver identical calibration curves, outlet pressure significantly affects the slope of the calibration curve, and the manufacturer calibration curve may not be appropriate for the operating conditions experienced with most center pivot installations, for a series of outlet pressures ranging from 207 to 690 kPa (30 to 100 psi). Bakeer (2002) and Badr *et al*. (2006) recommended avoiding fertigation devices that depend on the differential pressure between the inlet and outlet as much as possible and using hydraulically actuated chemigator for saving water, energy, and money. Some farmers inject the fertilizer through the irrigation system by the suction pipe of the irrigation water pumps, many of the farmers are used to it nowadays (39.4 %). EL Zuraiqi *et al*. (2004), and Jiusheng *et al*. (2007) stated that both manufacturing variability of emitters and injector types had a very significant effect on the uniformity of fertilizer applied, while the uniformity of water application was mainly dependent on emitter type. Using of positive displacement pump for fertilizer injection with drip irrigation system decreases emitter clogging compared with By-pass pressure mixing tank and venturi injectors. El Gendy *et. al*. (2009), and Kassem and Al-Suker (2009) reported that fertigation using injection pump records efficient and highest values of water and nitrogen use efficiency for wheat and barley crops, among different methods of fertilizer application used, according to the experimental results during 2006/2007 and 2007/2008 seasons in experimental farm conditions of Al-Qassim University. Tayel *et al*. (2010) concluded that an increase of garlic yield, water use efficiency and nitrogen use efficiency were obtained by using piston injector pump compared with using venturi or bypass pressurized mixing tank. Coates *et al*. (2012) reported that all fertigation techniques performed well, with fertilizer distribution uniformities between 0.88 and 0.96. Selection of the optimum site-specific fertigation strategy will depend on crop needs, scheduling limitations, and system design parameters such as emitter type, fluid travel time, and slope. The applications of expert system are rapidly increasing. Such applications are very affective in situations when the domain expert is not readily available (Negied, 2014). Objectives of this paper include an approach to assist proper fertigation-system selection with pressurized irrigation systems for different resources and conditions, with a set of qualifying resource-conditions based on expert system. Results were validated by consultation with domain experts and knowledge available from literature and pertinent experimentation, to accommodate validation of representative cases (A, B, C and D) using prepared and modified decision table. Some particular experiments were carried out to know hydraulic and engineering data of, a portable independent power injectors developed by Lithy (2012) in particular farm conditions to use it as a choice in proposed expert system program.

2. Materials and methods

Field experiments were conducted in a special farm in El Sharqia governorate included wide variety of parameters and field conditions to collect hydraulic and engineering data, about chemical injection unit developed by Lithy (2012) usable for comparing between systems, data for other systems including hydraulic and engineering criteria were taken from literature, accompanying system bulletin and field irrigation engineering experience. The author with committee including members of Agriculture Engineering Research Institute, Agriculture Engineering Department of Ain shames University, Agricultural Engineering Department of Al-Azhar University, Assiut, Egypt in addition to field agriculture and irrigation engineering experts, are domain experts. Four representation farms in different sites and conditions named case (A), (B), (C), and (D) shown in Table (1), were examined to represent extreme cases with wide variety of field resources and conditions.

2.1 Hydraulic and engineering characteristics of chemical injectors

The performance and required data, in addition to illustrative views of chemical injection systems used in proposed expert system, are presented in Table (2) and Figure 1 (a, b, c, d, e, f and g) as follows:

(1) Bypass differential tank (Figure 1a).
(2) Piston injection pump (Figure 1b).
(3) With suction pipe of irrigation pump (Figure 1c).
(4) Diaphragm injection pump (Figure 1d).
(5) Separate electric centrifugal injection pump. (Figure 1e).
(6) Venturi (Figure 1f).
(7) A portable unit with independent power injection (Lithy, 2012) (Figure 1g).

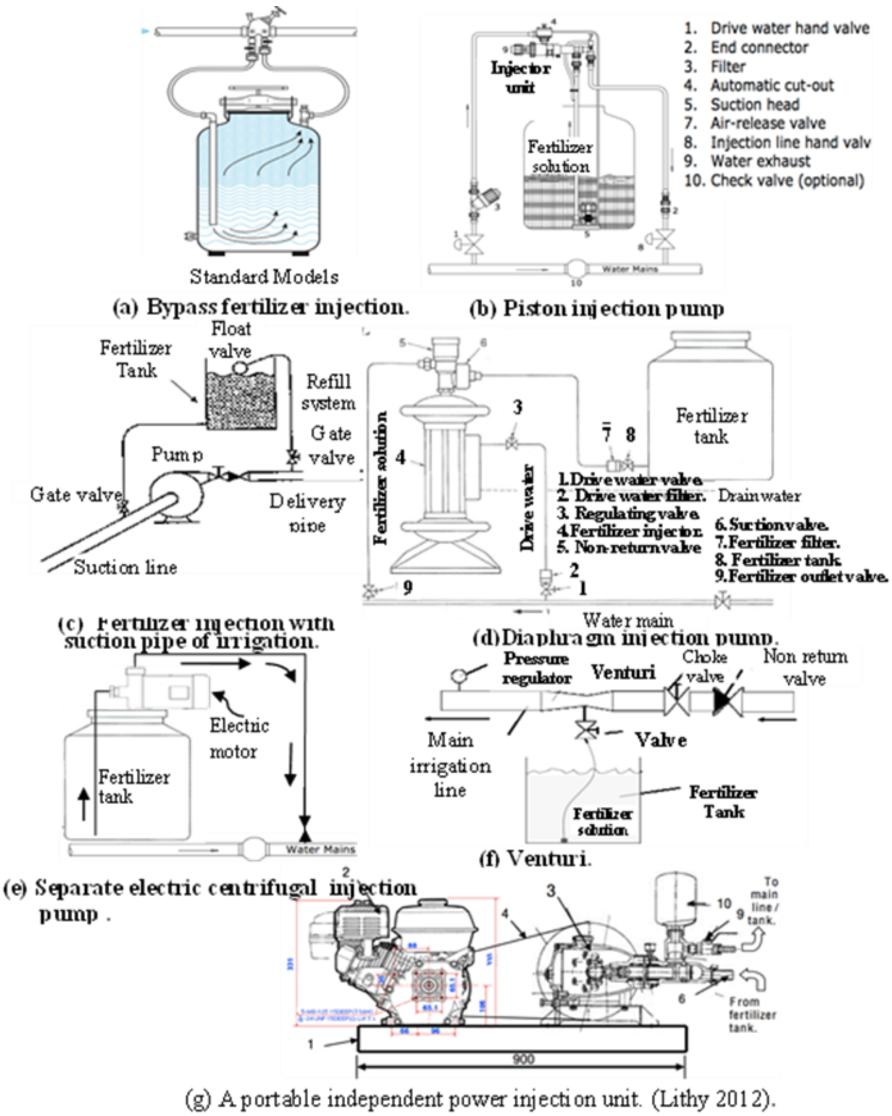

Figure (1): Illustrative views of chemical injection units.

Table (1): The actual farms condition under investigation including engineering and hydraulic criteria of irrigation system.

Farm conditions	Farm under case study			
	A	B	C	D
Location	Belbeis	Adleia	Adlia	Adlia
Area, feddan (feddan= 0.420 hectares)	70	8	8.5	10
Irrigation system	Drip	Drip	Sprinkler	Drip
Water source	Well	Ismailia Canal	Ismailia Canal	Under- ground reservoir
Crop	Mango	Orchard	Wheat & forage	Pomegranate
Agriculture spaces	4 × 2	6 × 3	0.12 × 0.15	3 × 3.5
Distance from water source and pump unit (m)	600	1600	800	150
Pump discharge (m^3/h)	120	130	120	70
System pressure, bar (kPa.)	3 (300)	1.5(150)	2.5 (250)	2.5 (250)
Irrigation time (h)	8-10	2	2	2-6
Average of chemical injection /irrigation time (m^3/h)	1.0	0.2-0.5	0.2-1.0	0.5-1.0
Power source	Electricity	Unavailable	Unavailable	Diesel

Table (2): Hydraulic and engineering specs for chemical injection techniques surveyed under investigation.

Injector specifications	Chemical injection technique						
	Bypass differential tank (Figure 1a)	Piston injection pump (Figure 1b)	With suction pipe of irrigation pump (Figure 1c)	Diaphragm injection pump (Figure 1d)	Separate electric centrifugal injection pump (Figure 1e)	Venturi (Figure 1f)	A portable with independent power injection unit (Lithy, 2012) (Figure 1g)
Operating pressure range, bar (kPa.)	2-8(200-800)	2-6(200-600)	2-4(200-400)	2-8(200-800)	2-4(200-400)	2-4(200-400	2-4(200-400)
Injection rate (m^3/h)	0.12-300	0.1- 0.25	0.1-1	0.1-0.25	0.1-1.8	0.1-0.20	0.1-1.2
Required power source	Hydraulic	Hydraulic	Electric/diesel	Hydraulic	Electric	Hydraulic	Independent petrol engine
Water consumption, m^3/m^3 of injected chemical	0	3	0	2	0	0	0
Connection, Inch (")	¾"	½"	1"	¾"	¾"	¾"-2"	¾"
Minimum filtration requirement (μm)	0	130	0	130	0	0	0
Total weight (kg)	75	5	0.5	12	18	0.75	39
Construction material	Steel	Chemical-resistant engineering plastics	Chemical-resistant engineering plastics	Stainless steel, natural rubber	Stainless steel	Chemical-resistant engineering plastics	Brass and natural rubber for stainless steel plunger seals

2.2 Procedure for the selection of the suitable chemical injector

The decision Table (3) was developed to present the system choices and qualifiers conditions prepared for the qualifiers, leading to choices of chemical injection systems, using methodology of Awady *et al*. (1997; 2002; 2003; 2006), Hassan and Sharaf (1997), El Diba (2017), Bedair (2018), and El-Sahn (2021). Each case study had scores of confidences for each chemical injection system, which indicate suitability to the circumstance impose. Virtual scores were allotted to different choices according to different qualifiers. Their assumption was based on experience and judgment of domain field engineering experts or extracted from literature such as Bakeer (2002), and Badr *et al*. (2006) in recommendation of using chemical injector to save money, energy and increasing of water and fertilizer use efficiency) or outcome of experiments (such hydraulic and engineering criteria of a portable chemical injector developed by Lithy (2012). Due consultations were held with domain experts to determine the qualifiers and test the outcomes of case studies, irregular outcomes were adjusted via values embedded in different rules, their effects were remark on target and correlated choices, this procedure was iterated until obtaining satisfactory results.

Table (3): Decision table.

Qualifiers	Chemical injection method						
	Bypass differential tank	Piston injection pump	With suction pipe of irrigation pump	Diaphragm injection pump	Sep. electric centrifugal injection pump	Venturi	A portable with independent power injection unit
1. Water source							
a- Open Canal	1.0	1.0	1.0	1.0	1.0	1.0	1.0
b-Well.	0. 5	1.0	-10	1.0	1.0	0.5	0.25
c- underground reservoir	0.25	0.5	1.0	0.5	0. 5	0.25	0.5
2. Irrigation system							
a- drip	1.0	1.0	1.0	1.0	1.0	1.0	1.0
b- sprinkler	0.25	0.75	1.0	0.75	1.0	0.25	1.0
3. Irrigation time							
a- Limited	0.25	0.75	1.0	0.75	1.0	0.5	1.0
b- unlimited	1.0	1.0	1.0	1.0	1.0	1.0	1.0
4. Irrigation system capacity /pump capacity ratio							
a. <1	0.0	0.75	-10	0.75	1.0	0.0	1.0
b. =1	1.0	1.0	1.0	1.0	1.0	1.0	1.0
5. System pressure							
a- >1.5 bar (150 kPa.)	1.0	1.0	1.0	1.0	1.0	1.0	1.0
b- <1.5 bar (150 kPa.)	0.0	0.0	1.0	0.0	1.0	0.0	1.0
6. Required injection rate							
a- > 0.250 m^3/h	0.0	0.0	1.0	0.0	1.0	0.0	1.0
b- <0.250 m^3/h	1.0	1.0	1.0	1.0	1.0	1.0	1.0
7. Injection time/ Irrigation time							
a- < 1	1.0	1.0	1.0	1.0	1.0	1.0	1.0
b- =1	0.0	0.0	1.0	0.0	1.0	0.0	1.0
8. Consumed water saving	1.0	0.0	1.0	0.0	1.0	1.0	1.0
9. Technical appropriateness							
a- Area≤ 8 feddan	0. 5	0.5	1.0	0.5	1.0	0.5	1.0
b- Area > 8 feddan	0.0	0.75	1.0	0.75	1.0	0.0	1.0
10. Power source available							
a- Electricity	0.5	1.0	1.0	1.0	1.0	0.5	0.0
b- Diesel	0.5	0.75	1.0	0.75	-10	0.5	0.25
c- Hydraulic	1.0	1.0	0.0	1.0	-10	1.0	0.0
d- Unavailable	0.0	0.0	0.0	0.0	-10	0.0	1.0
11. Clog resistance	0.0	1.0	0.5	1.0	0.5	0.0	1.0
12. Filtration requirement	0.75	0.0	0.75	0.0	0.75	0.75	0.75
13.Potential for localized injection	0.0	1.0	0.0	1.0	0.0	0.0	1.0
14. Technical labor req	1.0	0.0	1.0	0.0	1.0	1.0	1.0
15. Maintenance & operating cost	1.0	0.25	1.0	0.25	0. 5	1.0	0.0
16. Energy consumption	0.0	0.25	1.0	0.25	0.5	0.0	0.5
17. Initial cost saving	0. 5	0.25	1.0	0.25	0.5	0.5	0.25

2.3 Chemical injection systems choices and qualifiers

Systems under investigation included: (1) Bypass pressure differential tank, (2) Piston injection pump, (3) With suction pipe of irrigation pump, (4) Diaphragm injection pump, (5) Separate electric centrifugal pump, (6) Venturi, and (7) Independent power injection unit developed by Lithy (2012). The comparison between the different systems depends upon qualifier factors they included:

1. Water source: Including open canal, well, and underground reservoir.
2. Irrigation system: pressurized system under test was drip and sprinkler. Low credit given for required high pressure systems.
3. Irrigation time: Represent the limitation of irrigation time.

4. (Irrigation system capacity/ pump capacity) ratio: To give an indication on field distance from pumping unit and the appropriateness between irrigation capacity and pumping capacity and indicate. Number of plots irrigated according to pump capacity, so when (irrigation system capacity/ pump capacity) ratio less than 1 credit (-10) was giving to the choice of chemical injection with irrigation suction pipe to get logical results with other systems.
5. System pressure: Taken as indicator to the appropriateness of injection systems with actual system pressure whereas with low system presser systems required initial height pressure excluded and given low credit compared with other systems.
6. Required injection rate: Giving more credit for according to the rang of injection rate according to required injection rate.
7. Injection time /Irrigation time: Increasing injection time on irrigation time due to limited injection rate for injection system minimize credit of limited injection rate system and vice versa. Due to the high potential of planet over watering (Gorge and Allen, 1998).
8. Consumed water saving. The more injector water consumed the less credit system gains. And vice versa.
9. Technical appropriateness: increasing area gave more credit for high injector system rate.
10. Power source available: the available power source gave systems varying scores depending on power type require for each system, but when system need electricity in case of unavailable power, injection system (5) was given score of (-10) to gain logical results with other systems.
11. Clog resistance: Giving positive displacement pumps more credit than other injector models due to the potential of emitter clogging resistance (El Gendy *et al*., 2009).
12. Filtration requirement. Low credit was given to the hydraulic powered systems that require extra filtration according to the manufacturer recommendation.
13. Potential for localized injection: water and fertilizer use efficiency and crop yield were considered (Tayel *et al*., 2010) when giving scores to the injection systems injectors have the potential for localized chemical injection was given more credit (Piston, Diaphragm, Developed by Lithy (2012) than other systems.
14. Technical labor req. Low credit was given to the hydraulic powered systems that require highly qualified according to field engineering recommendations.
15. Maintenance and operating cost. Systems with high operating and maintenance cost was given low credit and vice versa.
16. Energy consumption. Low energy consumption was given low credit and vice versa.
17. Initial cost saving. High credit was given initial cost saving and vice versa.

2.4 Validation and case studies

Four actual trail cases were tested included extreme cases: Named case (A), (B), (C), and (D). The actual farms condition under investigation including engineering and hydraulic criteria of irrigation system conditions were presented in Table (2). Cases were exposed to consultation with domain experts for validation of decision table results. Each system of chemical injection was weighed under each suggested case. The manipulation of decision table done using excel software, the highest score represents the most system appropriateness for the case study.

3. Results and Discussion

Tables (4, 5, 6 and 7) show the selection tables of cases A, B, C, and D, derived from decision table to test the validation of proposed Expert system, for the cases under study. For each case a brief description of its conditions and data including engineering and hydraulic parameters of irrigation was shown in Table (2). Result scores are extracted below tables.

Table (4): Selection table for case (A).

Qualifiers	Chemical injection method						
	Bypass differential tank	Piston injection pump	With suction pipe of irrigation pump	Diaphragm injection pump	Separate electric centrifugal injection pump	Venturi	A portable with independent power injection unit
1b. Water source	0.5	1.0	-10	1.0	1.0	0.5	0.25
2a. Irrigation system	1.0	1.0	1.0	1.0	1.0	1.0	1.0
3b. Irrigation time	1.0	1.0	1.0	1.0	1.0	1.0	1.0
4b. Irrigation system capacity / pump capacity ratio	1.0	1.0	1.0	1.0	1.0	1.0	1.0
5a. System pressure	1.0	1.0	1.0	1.0	1.0	1.0	1.0
6a. Required injection rate	0.0	0.0	1.0	0.0	1.0	0.0	1.0
7a. Injection time/Irrigation time	1.0	1.0	1.0	1.0	1.0	1.0	1.0
8. Consumed water saving.	1.0	0.0	1.0	0.0	1.0	1.0	1.0
9b. Technical appropriateness	0.0	0.75	1.0	0.75	1.0	0.0	1.0
10a. Power source	0.5	1.0	1.0	1.0	1.0	0.5	0.0
11. Clogging resistance	0.0	1.0	0.5	1.0	0.5	0.0	1.0
12. Filtration requirement	0.75	0.0	0.75	0.0	0.75	0.75	0.75
13. Potential for localized injection	0.0	1.0	0.0	1.0	0.0	0.0	1.0
14. Technical labor req	1.0	0.0	1.0	0.0	1.0	1.0	1.0
15. Maintenance & operating cost	1.0	0.25	1.0	0.25	0. 5	1.0	0.0
16. Energy consumption	0.0	0.25	1.0	0.25	0.5	0.0	0.5
17. Initial cost saving	0. 5	0.25	1.0	0.25	0.5	0.5	0.25
Resulting scores	9.25	10.5	4.25	10. 5	13.25	10.25	12.75

According to results of selection Table (4) under field conditions briefed in Table (2) for case study (A), it is clear that injection system using separate electrical centrifugal pumps is the most appropriate system for chemical injection, due to gains the highest score compared with other systems that corroborate with farm conditions. Also results in Tables (5 and 6) for cases (B) and (C) corroborated using of independent power injection unit developed by Lithy (2012) for chemical injection as the most suitable system, that gains the highest score compared with other systems, although the wide variety differences in. While in case (D) that field conditions, hydraulic and engineering parameters presented in Table (2), results in selection Table (7) showed that the highest score of 15.25 gains for using the system with irrigation suction pipe of irrigation pump as the most appropriate choice for field conditions, hydraulic and engineering parameters briefed in table 2.

Table (5): Selection table for case (B).

Qualifiers	Chemical injection method						
	Bypass differential tank	Piston injection pump	With suction pipe of irrigation pump	Diaphragm injection pump	Separate electric centrifugal injection pump	Venturi	A portable with independent power injection unit
1b. Water source	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2a. Irrigation system	1.0	1.0	1.0	1.0	1.0	1.0	1.0
3b. Irrigation time	0.25	0.75	1.0	0.75	1.0	0.5	1.0
4b. Irrigation system capacity / pump capacity ratio	0.0	1.0	-10	1.0	1.0	0.0	1.0
5a. System pressure	0.0	0.0	1.0	0.0	1.0	0.0	1.0
6a. Required injection rate	0.0	0.0	1.0	0.0	1.0	0.0	1.0
7a. Injection time/Irrigation time	0.0	0.0	1.0	0.0	1.0	0.0	1.0
8. Consumed water saving.	1.0	0.0	1.0	0.0	1.0	1.0	1.0
9b. Technical appropriateness	0. 5	0.5	1.0	0.5	1.0	0.5	1.0
10a. Power source	0.0	0.0	0.0	0.0	-10	0.0	1.0
11. Clogging resistance	0.0	1.0	0.5	1.0	0.5	0.0	1.0
12. Filtration requirement	0.75	0.0	0.75	0.0	0.75	0.75	0.75
13. Potential for localized injection	0.0	1.0	0.0	1.0	0.0	0.0	1.0
14. Technical labor req	1.0	0.0	1.0	0.0	1.0	1.0	1.0
15. Maintenance & operating cost	1.0	0.25	1.0	0.25	0. 5	1.0	0.0
16. Energy consumption	0.0	0.25	1.0	0.25	0.5	0.0	0.5
17. Initial cost saving	0. 5	0.25	1.0	0.25	0.5	0.5	0.25
Resulting scores	6.0	7.0	3. 25	7.0	2.25	7.25	14.5

Table (6): Selection table for case (C).

Qualifiers	Chemical injection method						
	Bypass differential tank	Piston injection pump	With suction pipe of irrigation pump	Diaphragm injection pump	Separate electric centrifugal injection pump	Venturi	A portable with independent power injection unit
1b. Water source	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2a. Irrigation system	0.25	0.75	1.0	0.75	1.0	0.25	1.0
3b. Irrigation time	0.25	0.75	1.0	0.75	1.0	0.5	1.0
4b. Irrigation system capacity / pump capacity ratio	0.0	1.0	-10	1.0	1.0	0.0	1.0
5a. System pressure	1.0	1.0	1.0	1.0	1.0	1.0	1.0
6a. Required injection rate	0.0	0.0	1.0	0.0	1.0	0.0	1.0
7a. Injection time/Irrigation time	1.0	1.0	1.0	1.0	1.0	1.0	1.0
8. Consumed water saving.	1.0	0.0	1.0	0.0	1.0	1.0	1.0
9b. Technical appropriateness	0.0	0.75	1.0	0.75	1.0	0.0	1.0
10a. Power source	0.0	0.0	0.0	0.0	-10	0.0	1.0
11. Clogging resistance	0.0	1.0	0.5	1.0	0.5	0.0	1.0
12. Filtration requirement	0.75	0.0	0.75	0.0	0.75	0.75	0.75
13. Potential for localized injection	0.0	1.0	0.0	1.0	0.0	0.0	1.0
14. Technical labor req	1.0	0.0	1.0	0.0	1.0	1.0	1.0
15. Maintenance & operating cost	1.0	0.25	1.0	0.25	0. 5	1.0	0.0
16. Energy consumption	0.0	0.25	1.0	0.25	0.5	0.0	0. 5
17. Initial cost saving	0. 5	0.25	1.0	0.25	0.5	0.5	0.25
Resulting scores	7. 25	9.0	3.25	9.0	2.25	8.0	14.5

Table (5): Selection table for case (D).

Qualifiers	Chemical injection method						
	Bypass differential tank	Piston injection pump	With suction pipe of irrigation pump	Diaphragm injection pump	Separate electric centrifugal injection pump	Venturi	A portable with independent power injection unit
1b. Water source	0.25	0.5	1.0	0.5	0. 5	0.25	0.5
2a. Irrigation system	1.0	1.0	1.0	1.0	1.0	1.0	1.0
3b. Irrigation time	1.0	1.0	1.0	1.0	1.0	1.0	1.0
4b. Irrigation system capacity / pump capacity ratio	1.0	1.0	1.0	1.0	1.0	1.0	1.0
5a. System pressure	1.0	1.0	1.0	1.0	1.0	1.0	1.0
6a. Required injection rate	0.0	0.0	1.0	0.0	1.0	0.0	1.0
7a. Injection time/Irrigation time	1.0	1.0	1.0	1.0	1.0	1.0	1.0
8. Consumed water saving.	1.0	0.0	1.0	0.0	1.0	1.0	1.0
9b. Technical appropriateness	0.0	0.75	1.0	0.75	1.0	0.0	1.0
10a. Power source	0.5	0.75	1.0	0.75	-10	0.5	0.25
11. Clogging resistance	0.0	1.0	0.5	1.0	0.5	0.0	1.0
12. Filtration requirement	0.75	0.0	0.75	0.0	0.75	0.75	0.75
13. Potential for localized injection	0.0	1.0	0.0	1.0	0.0	0.0	1.0
14. Technical labor req	1.0	0.0	1.0	0.0	1.0	1.0	1.0
15. Maintenance & operating cost	1.0	0.25	1.0	0.25	0. 5	1.0	0.0
16. Energy consumption	0.0	0.25	1.0	0.25	0.5	0.0	0.5
17. Initial cost saving	0. 5	0.25	1.0	0.25	0.5	0.5	0.25
Resulting scores	9.5	9.75	15.25	9.75	1.25	10.0	13.25

4. Conclusion

The validation of cases showed that the proposed decision table can meet different situations with reasonable results. Figure (1) presents the resulting choices for the different situations under examination. Eminently in case (A) the choice of separate electrical centrifugal pump was evaluated highly (13.25) which about 43% above of all the choices. Also, from the same figure in cases (B) and (C) the selection table produced an independent power injection unit as the most appropriate system according to field conditions of each case although the wide variety difference in hydraulic and engineering parameters, (score 14.25) that confirmed with general field practice due to unavailability of power source with limited irrigation time and highly injection rate required. Finally for case (D) the results are logical for selection the choice of with suction pipe of irrigation pump (score 15.25, 37% above the average) with marginal advantages over other systems due to saving in initial cost, operating and maintenance cost.

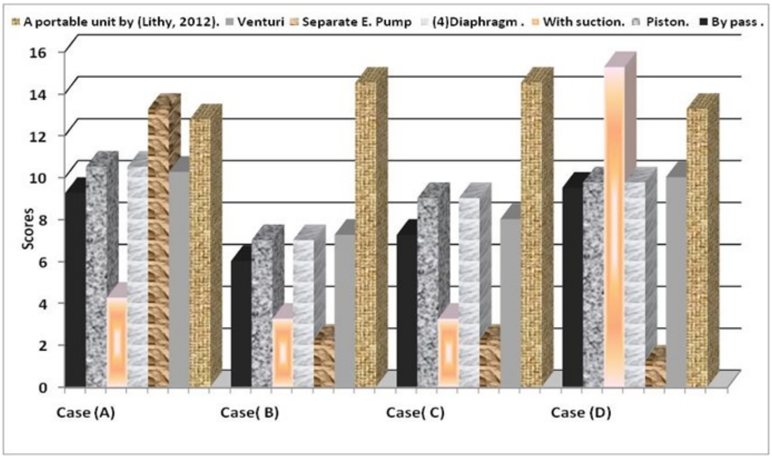

Figure (2): Scores of different chemical injector choices for representative situations.

In conclusion the validation cases proved the integrity of proposed Expert system that gave the best practice in judging extreme cases, and anticipated variants in between.

Acknowledgement

Authors acknowledge late Prof. Dr. Mohamed Nabli El Awady for his scientific advices and supporting during complete this research

References

Awady, M. N. (2016), "ES and their application in AE projects", In: *Computer applications in agricultural Engineering* (In Arabic), Chapter 7, Faculty of Agricultural Engineering, Al-Azhar University, Egypt, 86–100.

Awady, M. N., Kabany, A. G., and Attar, M. Z. (1997), "Expert-system based selection of farm machinery for Egyptian conditions", 5th conferences of *Misr Journal Agriculture Engineering*, Vol. 14 No. 4, pp. 121–131.

Awady, M. N., Mawla, H. A., Yehia, I. and Lithy, A. M. (2006), "Expert-system approach to assist cane delivery systems choice", 14th conferences of *Misr Journal Agriculture Engineering*, Vol. 23 No. 4, pp. 894–908.

Awady, M. N., Sallam, M. F. A. and Hegazi, A. M. (2002), "Expert-system approach for selecting mechanized irrigation systems for different situations", 14th conferences of *Misr Journal Agriculture Engineering*, Vol. 19 No. 2, pp. 285–296.

Awady, M. N., Yehia, I. and Hassan, M. A. (2003), "Pollination and service of date palm as choice in Expert-system", 11th conferences of *Misr Journal Agriculture Engineering*, Vol. 20 No. 4, pp. 1011–1024.

Badr, A. A., El-Ebabi, F. G. and ELtomy, E. O. (2006), "Fertigation methods effects on water and fertilizer uniformity in drip irrigation", *Misr Journal Agriculture Engineering*, Vol. 23 No. 1, pp. 122–136.

Bakeer, G. A. (2002), "Fertigation methods effects on water and fertilizer uniformity in drip irrigation", *Misr Journal Agriculture Engineering*, Vol. 19 No. 4 pp. 821–840.

Bedair, O. M. (2018), "Narrowly-bounded turf irrigation system selection using "expert system" approach", *Misr Journal Agriculture Engineering*, Vol. 35 No. 1 pp. 69–90.

Caleder, T. and Bert, J. (2007), "Selection of fertigation equipment", available at http://www.agric.wa.gov.au/objtwr/imported_assets/content/hort/eng/f03501.pdf.

El Diba, M. M. (2017), *Expert System for true management*, Ph.D. Thesis, Agricultural Engineering Department, Faculty of Agriculture, Ain Shams University, Egypt, pp. 5–70.

EL Zuraiqi, S., Rusan, M. J. and Al Qawasmi, W. (2004), *Fertigation in Jordan, IPI regional workshop on potassium and fertigation development in West Asia and North Africa*, Rabat, Morocco, pp. 24–28.

El-Gindy, A. M., Tayel, M. Y., El-Bagoury, K. F. and Sabreen, Kh. A. (2009), "Effect of injector type and nitrogen treatment on emitters clogging", *Misr Journal Agriculture Engineering*, Vol. 26 No. 3, pp. 1263–1276.

El-Sahn, O. M. N. (2021), "Expert system to determine a proper control method for certain hemipterous (Hemiptera) insects according to site conditions", *Egyptian Journal of Plant Protection Research Institute*, Vol. 4 No. 3, pp. 352–372.

Gorge, J. H. and Allen, G. S. (1998), "Fertilizer application and management for micro drip irrigated vegetables in Florida", Circular 1181, available at http://hammock.ifas.ufl.edu.

Hassan, A. A. and Sharaf, G. A. (1997), "Expert system for evaluating micro irrigation systems", 5th conferences of *Misr Journal Agriculture Engineering*, Vol. 14 No. 4, pp. 77–86.

Janos, L. (1995), "Application of chemicals through irrigation systems", *ICID Journal*, Vol. 45 No. 2, pp. 125–146.

Kassem, M. A. and Al-Suker, A. (2009), "Effect of fertigation methods on productivity and nitrogen use efficiency for wheat and barly crops", *Misr Journal Agriculture Engineering*, Vol. 26 No. 2, pp. 866–885.

Kranz, W. L., Eisenhauer, D. E. and Parkhurst, A. M. (1996), "Calibration accuracy of chemical injection devices", *Applied Engineering in Agriculture*, Vol. 12 No. 2, pp. 189–196.

Li, J., Meng, Y. and Li, B. (2007), "Field evaluation of fertigation uniformity as affected by injector type and manufacturing variability of emitters", *Irrigation Science*, Vol. 25 No. 2 pp. 117–125.

Lithy, A. M. (2012), "A portable chemical injection unit for irrigation systems", *Misr Journal Agriculture Engineering*, Vol. 29 No. 3, pp. 1015–1030.

Negied, N. K. (2014), "Expert system for wheat yields protection in Egypt (ESWYP)", *International Journal of Innovative Technology and Exploring Engineering*, Vol. 3 No. 11, pp. 1–4.

Robert, W. C., Sahoo, P. K., Schwankl, L. J. and Delwiche, M. J. (2012), "Fertigation techniques for use with multiple hydrozones in simultaneous operation", *Precision Agriculture*, Vol. 13 No. 2, pp. 219–235.

Tayel, M. Y., Shaaban S. M., Ebtisam I. D. and Sabreen, Kh. (2010), "Effect of injector types, irrigation and nitrogen levels on II- Garlic yield, water and nitrogen use efficiency", *Journal of American Science*, Vol. 6 No. 11 pp. 38–46.