EFFECT OF TECHNICAL OPERATING CONDITIONS OF CENTRAL PIVOT ON OPTIMIZING WATER-USE FOR SOME VEGETABLE CROPS

By

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B. Sc. Agric. Sc. (Agric. Engineering), Cairo University, 2002

A thesis submitted in partial fulfillment

of

the requirements for the degree of

MASTER OF SCIENCE

in

Agricultural Science

(Agricultural Mechanization)

Department of Agricultural Engineering

Faculty of Agriculture

Ain Shams University

2009

Approval Sheet

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Date of Examination: 29 / 3 / 2009

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ACKNOWLEDGEMENT

The author wishes to thank "**Allah**" for the completion of this work.

The author further wishes to express her greatest appreciation and deepest gratitude to **Prof. Dr. Abdel- Ghany M. El- Gindy**, Prof. Emeritus of Agric. Eng., Fac. of Agric., Ain Shams Univ. for suggesting the theme of this research; kind guidance, encouragement and providing all the required facilities.

Special thanks are due to **Prof. Dr. Saeed Abdel-Hay Wahba,** Research Professor of Soils and Water Relations, National Research Center, for supervising, revising and precious advices during the course of the work.

Sincere appreciation for supervision and guidance of **Prof. Dr. Mohamed Yossef Tayel,** Research Professor of Soils and Water Relations of National Research Center.

Also, special gratitude towards **Dr. Ahmed Abou El- Hassan Abdel- Aziz.,** Assoc. Prof. of Agric. Eng., Fac. of Agric., Ain Shams Univ. for his advices and continuous support to fulfill this work.

Great thanks to **father, mother, sisters** and all members of my family for their support during my whole study.

Also, I would like to express my deepest appreciation to **my husband** and **my son "Mohaned"** for his kind help, great efforts during preparation of this study.

Thanks are extended to the authorities of the **National Research Center,** for financial support and facilities introduced to achieve this work.

Thanks to all who had lent me a hand to complete this research work.

ABSTRACT

Marwa Mahmoud Abd-ELbaset: Effect of Technical Operating Conditions of Center Pivot on Optimizing Water - Use for Some Vegetable Crops. Unpublished M. Sc. Thesis, Department of Agricultural Engineering, of Ain Shams University, 2009.

Field experiments were carried out at the Experimental Farm of Faculty of Agriculture; Ain shams University, to study the effect of some technical operating conditions of pivot irrigation system on water distribution uniformity and some physical properties of the soil. Studied technical parameters were: 1) four operating pressure (150, 200, 250 and 300 kPa); 2) two sprinklers heights over the plant Canopy (1.5 and 2.5m); 3), three temperature degrees of the daylong (30C^{o} "morning", 35C^{o} "2.0 pm" and 32C^{o} "5.0 pm") and 4) three wind speeds (1.4, 5 and 6 m/s).

Results indicated that water distribution uniformity increased had been from 86.7 % to 93.9 % with increasing the operating pressure from 150 to 300 kPa at 1.5m sprinkler height. While it decreased from 93.9% to 76.7% with increasing the sprinklers height from 1.5 m to 2.5 m at operating pressure of 300 kPa. The water distribution uniformity decreased from 93.9% to 85.5% by the temperature increase from 30 C^{o} to 35 C^{o} at sprinklers height of 1.5m and operating pressure of 300 kPa. The water distribution uniformity decreased from 83.5% to 64.7% by the wind speed increase from 1.4 m/s to 6 m/s. Some-small positive effect for the pivot sprinkler irrigation system on some water soil properties i.e., P.W.P and H.C were noticed at the end of 2nd irrigation season. The moisture content under different irrigation water treatments at sprinklers height 1.5m from the soil surface was higher than 2.5 m height. Water use efficiency for total dry bulbs yield at 50% of ETc was 23.6 kg/m^{3}, while it was 10.8 kg/m^{3} at 100% of ETc. The highest growth parameter and yield measurements were obtained at 75% ETc.

Keywords: Center pivot, Water regime, Energy requirements, Costs, Onion, vegetable crops.

I-INTRODUCTION

Most of agricultural land in the Nile Valley and Delta are mainly irrigated using surface irrigation method which is quiet low in its efficiency (50%). Due to the limited water resources, hot and dry climate and fast increase of population in Egypt, more water is required for horizontal expansion.

In the last decades, increasing areas of the newly reclaimed land is being introduced to exploitation using pressurized irrigation systems, one of which is the center pivot irrigation system (CPIS). The application efficiency and optimum operating conditions of these appliances have not been studied sufficiently under the Egyptian conditions. Therefore, using the pressurized irrigation systems, as well as developing surface irrigation systems can save considerable amounts of irrigation water to be used in horizontal expansion.

The proposed approach of the present study implied assessment the effect of different technical operation conditions of center pivot irrigation system on its efficiency. Some soil properties and water- use efficiency, as well as, the productivity and quality of cultivated crop under this system.

Center pivot irrigation system is considered as the most appropriate investment and suitable mean to irrigate large scale areas, which can be economically cultivated with different crop patterns.

This study aimed to:

1) assessment of most suitable operating conditions of center pivot irrigation system for optimizing its efficiency.
2) study the effect of different irrigation water regimes on the productivity, quality and net return of water use by onion crop under center pivot irrigation system.

II- REVIEW OF LITERATURES

2-1- History:

According to FAO (1980), center pivot irrigation was invented in the United States of America. However the first machine was manufactured in Nebraska in 1949. The system was designed to irrigate circles of a very large radius, using practically no manual labour and deducting only a very small part of the hydraulic power furnished by the pumping mechanism in order to move the machine. Center pivots have been continuously improved since that period and the technique has changed. For example, forward movement is attained by electrical power, thus often abandoning the principal idea of the inventor.

The USSR and Eastern European countries have used center pivots on very large farming estates. Large irrigation projects are carried out with machines of this type in many countries around the world such as Canada, certain Latin American states, Libya and KSA.

The limited dimensions and the irregular shapes of the fields are not favorable to the introduction of center pivots. **Heermann and Spofford (2000)** indicated that centre pivot irrigation systems have expanded such that they now represent almost one-third of the total irrigated area in the USA. Their use is expanding globally as well. Field evaluation performance standards for centre pivot systems were developed for high pressure impact sprinkler application devices. They have been slightly modified for low pressure application devices, now used on the majority of the systems. Industry is expressing difficulty with the application and appropriateness of these standards on present day systems. Precision agriculture is adding a new dimension to the need for not only applying uniform irrigation but also meeting the objectives of variable rate applications of water based on soil and crop water requirements. The authors reviewed the current field testing procedures in use for centre pivot sprinkler system evaluations and analyzed the problems with these procedures. A simulation model was used to illustrate the pros and cons of various techniques. Recommendations are provided for major changes in the testing and evaluation of centre pivot and linear move irrigation systems.

2-2- Factors affecting water distribution under pivot system:

Fangmeier et al. (1990) developed a computer model for estimating the effect of movement and delivery of low pressure center pivot and linear- move systems with furrow drops on water distribution uniformities. Results indicated that with increasing the system speed, uniformities with short check spacings increased. Check spacings of 3 m or greater speed had no effect with the center pivot but varied over a 10% range for the linear move. To obtain a uniformity coefficient of 0.8, check spacings needed to be at least 2 m. Uniformities were greatly improved if the alignment angles between spans, which controlled tower movements, were reduced from 0.9- 0.4 degrees or 0.25 degrees. However, this caused more frequent movement of the center towers which requires more expensive equipment.

Hanson and Orloff (1996) compared both rotator and spray sprinklers on centre-pivot sprinkler machines. The uniformity of applied water was higher for the rotator sprinklers. On the other hand, under windy conditions, water uniformity increased with spray sprinklers and decreased with rotator ones. Modifications of sprinkler spacing were recommended when using rotator sprinklers.

Cainelli et al. (1998) evaluated some characteristics of centre pivot irrigation system equipment, and determined the water distribution uniformity, under and over the soil surface. The Christiansen uniformity coefficient (CUC) and Christiansen uniformity distribution (CUD) were used to evaluate the system. A low pressure centre pivot was tested in four different speeds: 25, 50, 75 and 100% of the timer sensor, and in four collectors lines spaced. Results indicated that both coefficients presented good performance. The values of CUC and CUD were above the minimum recommended for an irrigated corn [maize] field. The uniformity coefficients in all depths of the soil were higher than that above the soil surface. However, the uniformity under soil surface increased with the time in all depths.

Kincaid et al. (2000) reviewed the last decade development of some new and innovative sprinkler/spray head designs for using with center pivots and traveling laterals. They reported that the impetus behind these devices has been the need to maintain uniformity of water application equivalent to the high pressure overhead sprinklers, while reducing energy requirements, spray drift losses, and controlling potential runoff. However, spray head designs have evolved from the simple smooth or grooved fixed-deflector plates to rotating or oscillating plates designed to produce larger patterns or control droplet sizes. Pattern diameters produced with various types of spray plates operating at various nozzle pressures, and nozzle elevations were given and uniformity attainable on moving laterals was discussed.

Clark et al. (2003) stated that evaporation and wind losses could be higher with the lower operating pressures, thus reducing the overall application efficiency. Based on the spacing, nozzle size, and operating pressure scenarios tested in this research, sprinkler spacing to wetted diameter ratios should not exceed 0.20 in order to achieve coefficients of uniformity in excess of 90 under no- wind conditions with fixed- plate, LDN-type sprinklers.

Abdel-Rahman (2005) stated that center pivot modification depends on replacing the sprinkler head (sprayers) by polyethylene hoses ending by nozzle were selected using two different nozzles shapes trapezoid and triangle and was cultivated by maize. Results showed that, operating the modified pivot system at low pressure head (1.5bar) had decreased water amount by (16.8%) compared to the normal sprinkler pivot system, the uniformity coefficient for the triangle shaped nozzle was 91.6% furthermore, pulled hoses (200cm) were better than the short hoses (25 cm). Water use efficiency (WUE) with modified normal pivot system was (2.5 kg/m^3) compared to the pivot system (1.84 kg/m^3).

Kincaid (2005) stated that many of developed sprinklers or spray heads can produce high application uniformity with controlled drop sizes and medium sized pattern widths at medium to low pressures.

Silva (2006) studied the effect of spray head sprinklers with different deflector plates on irrigation uniformity, runoff and sediment yield in a Mediterranean soil. Field tests using low-pressure (140 kPa) spray head sprinklers with smooth and medium groove deflector plates and maximum water applications rates between 99 and 125 mm/h were carried out in a Mediterranean soil. Medium groove deflectors produce lower irrigation uniformity, but apply water with larger water droplets which are less affected by wind and can lead to less evaporation and wind drift losses. However, these droplets have higher impact energy over the soil surface, increasing surface sealing and crust formation, which reduce infiltration and increase runoff. Higher runoff amounts and soil particles detachment produced by grooved deflectors also lead to more sediment yield and soil erosion.

2-3-Performance of center pivot irrigation system:

Thomson, et al. (1982) evaluated microprocessor based irrigation system controller on a small centre pivot to assess the performance of the programmed algorithms under field conditions and to establish criteria for improving these algorithms. More sophisticated control algorithms are proposed which should increase water use efficiency.

Omary and Sumner (1998 and 2001) developed a model and computer program to calculate water distribution, application depth and uniformity coefficient for spray nozzles mounted on a centre pivot system. The program required two basic inputs: first, the experimental data for the static distribution pattern of the nozzle, including collection time, spacing between collection cups, cups opening radius, and volume of water collected and the second, irrigation system inputs including spacing between spray nozzles, distal end tower moving velocity, distance of nozzle from the centre pivot, move-stop cycle time, and percentage of moving time during the cycle. Experiments were conducted to validate the simulation using various moving velocities, spacings and cycle times, and percentage of moving time of the cycle.

Oliveira et al. (2003) evaluated the action of an overhead irrigation of the type central pivot of low pressure, in relation to the distribution of water in the surface and in the 0-20 and 20-40 cm layers of soil. The evaluations were done in two positions of the central pivot equipment, characterized by two types of soil handling, preparation of the soil with levelling discing (P1) and no-tillage (P2). The analysis the uniformity of water application was done by the coefficients of uniformity of Christiansen (CUC) and of distribution (CUD), calculated starting from precipitation data, collected according to described methodology. The pivot evaluated presented coefficient uniformity Christiansen (CUC) and Christiansen uniformity distribution (CUD) above the recommended minimum of 80%, in the two preparation systems and in the soil layers studied, the uniformity coefficients were superior to those obtained in the surface of the soil, increasing with the time until the limit of 24 hours after the irrigation, indicating a good redistribution of water in the soil profile.

Oliveira et al. (2004) evaluated the performance of centre pivot systems in western Bahia from irrigation uniformity indicators, irrigation adequacy and efficiency, field tests were conducted in systems of eleven farms in Barreiras and Bom Jesus Da Lapa. According to the radial uniformity coefficient, irrigation uniformity varied from 67.6 to 92.4%, averaging 83%, and the greatest number of pivots showed coefficient between 80 and 90%. The low quarter potential efficiency averaged 89.5%.

2-4- Onion crop response to sprinkler irrigation system:

2-4-1-Effect of water regime on Onion yield:

El-Tabbakh et al. (1979) reported that high soil moisture content increased the height of onion plant. Also, **Abd-Alla (1992)** studied the effect of soil moisture content on onion plant. His results indicated that high soil moisture content was more effective in increasing the plant length than other treatments. Moreover, **Galbiatti et al. (1992)** investigated the effect of four irrigation levels, i.e,. 25, 50, 100 and 150% of daily evaporation on onion growth. They found that increasing irrigation level increased the onion plant height.

Barnoczki (1982) studied the effect of irrigation on six onion cultivars. He reported that irrigation generally increased onion yield. In addition, **Hassan (1984)** investigated the effect of irrigation on onion yield. He showed that irrigated onion with 7 and 10 days intervals increased the total yield comparing with 14 days intervals.

Martin et al. (1994) studied the effect of different irrigation scheduling on growth and production of onion and found that irrigated onion with 100% and 120% of Etc. based on daily evaporation increased the leaf area/ plant as well as the bulb diameter and length during the growing.

El-Haris and Abdel-Razek (1997) reported that two-years field studies were conducted on onion (Allium cepa) grown in sandy soil using a line-source sprinkler system that providing a gradual water application to determine the influence of the amount of irrigation water on yield and growth characteristics. Growth characteristics, and yield components generally improved with the increase in total water application of the growing period. Total yield increased by 89% (81.3-153.9 Mg/ha) and

92% (87.7-168.4 Mg/ha), water use efficiency for total yield (WUEt) by 16.7 and 18.8%, and water use efficiency for bulb yield (WUEb) by 16.6 and 20.4% as the total water applied raised from 425 and 462 mm to 749 and 687 mm, in the 1994/95 and 1995/96 seasons, respectively.

Mohamed and Gamie (2000) investigated the effects of irrigation treatments (after a depletion of 35-40, 55-60 and 75-80% of the available soil water (designated as wet, semi-wet and dry, respectively)) on onion cultivars (Giza-6M, Giza 20, Shandweel-1, Assiut Glob, El-Bostan and Beheary No Pink) during seasons of (1996/1997) and (1997/1998). The total, marketable and exportable yields, and average bulb weight, significantly increased, while total soluble solids (TSS) declined with increasing available soil moisture. Giza 20 produced the highest total and marketable yields, and TSS (except during 1996/97), while El-Bostan had the highest average bulb weight. Water consumptive use and water use efficiency were higher in 1996/97 than in 1997/98. Water consumptive use and water use efficiency were highest in Beheary No Pink and Giza 20, respectively.

Pirov (2001) indicated that if onions are to be used fairly quickly, then maximum yields can be achieved by keeping the soil at 80-90% of field capacity. However, if they are to be stored for a long time then it is best to keep the soil at 70% of field capacity throughout the growing season.

Meranzova and Babrikov (2002) studied the seasonal water requirements of long-day onion cv. Santana grown under optimum irrigation schedule during 1996-97 in Plovdiv, Bulgaria. Three variants with different irrigation rates (1.00, 0.75 and 0.50 IR) were created using a microsprinkler system. The optimum variant (1.00 IR) had an average total water supply of 213 mm, while the other variants, 0.75 and 0.50 IR, had total water supplies of 162 and 110 mm, respectively. The number of irrigation applied was 9 during the first year and 8 during the second year.