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ASSESSMENT OF SPRINKLER IRRIGATION SYSTEM AS A SUPPLEMENTAL IRRIGATION FOR WHEAT CROP PRODUCTION UNDER RAIN FED CONDITIONS IN NORTH SINAI- EGYPT.

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ABSTRACT

Due to the drought and water scarcity, which is one of the obstacles to development in arid and semi-arid areas that depends on rain-fed agriculture and rain water only, wheat crop exposed to water shortage after the rain stopped, especially in the critical period during the formation and filling stage of the grain causing poor productivity, the yield is highly positively affected by using an additional irrigation source. So, this research was aimed to increasing wheat productivity by applying sprinkler supplemental irrigation for watering wheat in its critical period and maximizing the irrigation Water Use Efficiency (WUE) to raise the Water Use Productivity (WUP) in cultivated area as one of the tools for a climate changes challenges. The experiment was applied in North Sinai Governorate during winter season of 2021/2022. The study was conducted to determine the effect of optimum watering rates of the supplemental irrigation system on maximizing wheat productivity and water use efficiency under the drought and water scarcity conditions. Irrigation treatments was, (33% - 50% - 65%) of full daily irrigation rate compared to the traditional system without irrigation based on rain water only. Two seeding rates were used for cultivation: (48 and 60 kg.fed^{-1}). The results showed that treatment using supplemental irrigation at 65% of the actual water needs with seeding rate of 48 kg.fed^{-1}, achieved the highest values for crop productivity, (WUE) and (WUP) which reached to 1660 kg.fed^{-1}, 2.83kg.m^{-3} and 11.90 kg.fed^{-1}.mm^{-1} respectively, While T_2 (33% irrigation + 60 kg.fed-1 seeds for planting) and T_7 (Rain-fed condition) released the lowest values compared to other treatments.

Key Words: supplemental irrigation, rain-fed, moisture content, water use efficiency and wheat yield.

INTRODUCTION

Dryland regions are characterized by low rainfall, high evapotranspiration, high temperatures and poor productivity. Drought is one of the most important factors that reduces wheat production, Grain yield were negatively affected by water stress **(Laura *et al.*, 2008).**

Climatic change in marginal coastal zone of Egypt would increase drought with high fluctuation in precipitation **(FAO, 2008).**Thus its grain yield is highly positively affected by supplemental irrigation **(Al-Ghzawi *et al.,* 2018).** In arid and semi-arid regions water scarcity and low rainfall affects the agricultural activities. Rainfall is low value and uneven distribution. Several factors can affect agricultural production, but water is the most important factor **(Oweis and Hachum, 2006).** Water is the main limiting factor for winter wheat production, and irrigation is essential for maintaining high winter wheat yields **(Xu *et al.,* 2018).** Total Wheat cultivated area in the world was about 215 million hectares during the 2017/2018 season which produced about 734.74 million tons (3.24 tan/ha.), **(USDA, 2018).** This will control the future of food security of the world, particularly under the existence of large gap among wheat production and consumption. The irrigation occurs in the arid and semi-arid regions where there is insufficient rainfall to uphold crop growth In these areas. The precipitation at the coastal zone is highly changeable and less than water consumption of wheat, When the annual rainfall is large, but its pattern includes several inter-seasonal drought, crops are then subject to severe loss. This becomes worse if the drought is long and coincides with the period that critically affects the growth of the cultivated crop **(Kannan *et al.,* 2010)**. Water is regarded as a necessary component of environmental development **(Frone, and Frone 2015)**. Rainwater productivity can be significantly improved when it is combined with specific irrigation system, such as supplemental irrigation which can be an efficient technique to cope with the limited water availability **(Oweis and Hachum , 2012).** Irrigation is the main way to meet the water demands for the growth, development and yield formation of winter wheat **(Jha *et al.,* 2017)**. Using limited amount of water as a supplemental irrigation can improve both the crop productivity and increase the water use efficiency **(Man *et al.,* 2016).** So, supplemental irrigation could be the most appropriate method to improve wheat yield in these regions, which suffering from drought, and insufficient fresh water especially under climatic change and rainfall scarcity **(Abderrazzak *et al.,* 2013).** Supplemental irrigation is defined as the application of limited amounts of water during critical crop growth stages to essentially rain-fed crops to improve and stabilize yields by maintaining a minimum amount of soil moisture in the root zone **(Nangia and Oweis , 2016)**. The water requirement of winter wheat reaches its peak in April and May **(Zhang *et al.,* 2013).** Reducing the frequency of irrigation and thereby reducing the total irrigation water input can potentially increase WUE **(Zhang *et al.*, 2018).** Supplemental irrigation decreases damage caused by drought conditions **(Ali *et al.*, 2019).** Adding different supplemental irrigation quantities at certain specific growth stages of wheat increased significantly grain yield **(Erekul *et al.*, 2012 and Tadayon *et al.*, 2012).** The low amount of rain during the winter wheat growing seasons only provides 30% of the crop water requirements, and almost 70% of irrigation water is required to maintain the potential yield of wheat **(Ouda, 2016).** Many researchers have agreed that localized irrigation has been considered the best technique over recent decades for protecting soil and enhancing water resources benefits **(Muller *et al*., 2016).** Supplemental irrigation is one of the efficient methods for increasing the water use efficiency in agricultural system complementing the insufficient rainfall to combat with the drawbacks of drought stress**, (Singh *et al*.,2010).**Therefore, the research was aimed to maximize the wheat yield and water use efficiency of sprinkler supplemental irrigation to mitigate the negative effects of long droughts through increasing soil wetting specially during the filling period of wheat grain to maximize the importance of water drop in confrontation of water scarcity challenges.

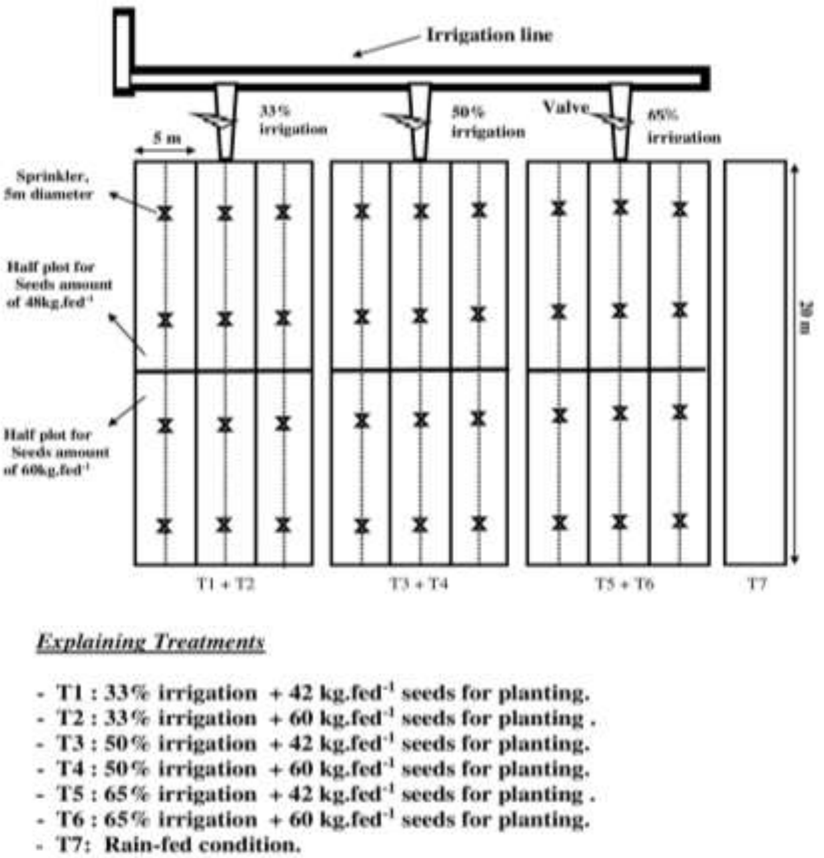
MATERIALS AND METHODS

Experimental Site Description:

The field experiment was conducted in a private farm, El-Arish, North Sinai (30° 06' 03.2" N, 32° 43' 35 " E), Egypt during the winter season of 2021/2022. Soil texture was sandy with an average pH of 8.17 and organic matter content of 0.16%. The available N, P and K contents were 8.0, 6.32 and 192 ppm. This research was aimed to determine the effect of sprinkler supplemental irrigation system on wheat yield production and water use efficiency with different treatments of amount water applied (33% - 50% - 65%) of daily full irrigation and wheat seeding rates cultivars, Sakha-93, (48 $kg.fed^{-1}$ and 60 $kg.fed^{-1}$) used in agriculture in a comparison with rain-fed condition (Non-irrigation). Treatments were arranged in split-split plot design in three replicates for each treatment. An area of 1000 m^2 was divided to three plot for each irrigation pattern (main plots), every plot comprised three manifold irrigation line as a three replicates for each irrigation treatment, four sprinklers for each line, wheat seeding rate treatments were arranged in every a half plot as shown in **Fig(1)**. Grains were sown manually. Traditional agricultural treatment, (rain-fed) were carried out as recommended for wheat growing under the conditions of North Sinai as a semi-arid land.

Field experiment treatments:

- T1 : 33% irrigation + 42 kg.fed-1 seeds for planting.
- T2 : 33% irrigation + 60 kg.fed-1 seeds for planting .
- T3 : 50% irrigation + 42 kg.fed-1 seeds for planting.
- T4 : 50% irrigation + 60 kg.fed-1 seeds for planting.
- T5 : 65% irrigation + 42 kg.fed-1 seeds for planting
- T6 : 65% irrigation + 60 kg.fed-1 seeds for planting.
- T7: Rain-fed condition.



Fig(1):Experemintal field design and supplemental irrigation treatments.

Supplemental irrigation was started to apply in the last week of March when the rain stopped, which is also a critical period for filling wheat grains. Three supplementary irrigations were carried out, one irrigation every week for all treatments. Irrigation rates were 33%, 50% and 65% of daily full irrigation which is ranged from 20 to 25 mm/day equivalent to100 $m^3.fed^{-1}$. then the supplemental irrigation rates as a treatments was (33 , 50 and 65 $m^3.fed^{-1}$) which is equal to respectively , 99 , 150 and 199 $m^3.fed^{-1}$ as a total water applied through three irrigations . Wheat supplemental irrigation was showed in **Fig (2).**

Fig (2): In field wheat supplemental sprinkler irrigation.

Measurements:

Rain Fall Amount

By a digital automatic rain fall gauge, rainfall amount was recorded for each storm during the winter season.

Wheat Yield Production.

The average yield of wheat crop for all treatments was determined. For every treatment, three Samples for each treatments were taken randomly from one square meter and manually harvested and threshed, separated grain were weighted, then calculated as average, $kg.m^{-2}$ and $kg.fed^{-1}$.

Water Use Efficiency, (WUE).

According to wheat yield production, ($kg.fed^{-1}$) and irrigation water applied per feddan, ($m^3.fed^{-1}$),WUE was calculated according to the following formula:

$$\text{WUE, kg.m}^{-3} = \frac{crop\ yield\ , kg.\ fed^{-1}}{water\ \ applied\ \ , m^{3}.\ fed^{-1}}$$

Water Use Productivity, (WUP).

When one mm water depth applied for one feddan, this is equal to size 4.2 m^3, and according to the wheat productivity, WUP was calculated a according to the following formula:

$$\text{WUP, kg.fed}^{-1}\text{.mm}^{-1} = \frac{crop\ yield\ , kg.\ fed^{-1}}{total\ water applied\ , mm}$$

$$\text{Total water applied, mm} = \frac{total\ \ water\ \ applied\ , m^{3}}{4.2\, m^{3}}$$

When, one mm water irrigation depth for area 4200m^2 is equal to water size 4.2 m^3

Economic Water Use Productivity, (EWUP).

Economic water use productivity (EWUP) was calculated according to, **Abou-Baker *et al.* (2012)** formula as following:

$$EWUP = \frac{encom\ from\ one\ \ feddan\ (Egyptian\ Pound\ /\ \ fed\ )}{Totall\ water\ applied\ , m^{3}\ /\ \ fed}$$

RESULTS AND DISCUSSION

Rainfall Amount:

Rainfall events and the total storm are illustrated in **Fig (3)**. Winter rain spells of season 2021/ 2022 started from October 2021 to April 2022, which reached to 124mm. The difference between monthly rainfall was observed. The highest event storm was 34.3 mm in January 2022 which is considered the highest cumulative rainfall month. While the lowest storm was 8.7mm in October 2021.The rain-poor period was at the beginning and end of the season in October and March which recorded 8.7 and 11.5 respectively. The abundant months were December, January and February which recorded the highest storms of 28.5, 34.3 and 25mm respectively.

Wheat Yield Production.

Data in **Fig (4)** illustrated that different treatments, wheat grain yield varied from 823 to 1660 kg.fed^{-1} during the winter season 2021/2022. T**7** treatment based on rain-fed recorded the lowest productivity of 823 kg.fed^{-1} compared to the other treatments applied supplemental irrigation. T5 and T6 treatments achieved the highest yield of 1660 and 1521kg.fed^{-1} respectively. In generally increasing supplemental irrigation water applied and decreasing seeding rate increased wheat yield. So, T5,T6 > T3,T4 > T1,T2 > T7, with yield of 1660,1521 > 1387,1170 > 1165,1024 > 823 kg.fed^{-1} respectively. This is attributed to that increasing water applied for wheat crop Increases soil moisture and protects plants from drought stress. **Laura *et al.* (2008)** found that grain yield and dry matter were negatively affected by water stress, especially in the filling periods when rain stops**.** Supplemental irrigation during this critical period prevents grain atrophy and increases its weight and improves productivity**.** The supplemental irrigation caused the grain yield to increase significantly up to 58% **(Erekul *et al.*, 2012)***.* Also, on the same path, reducing seeding rates reduces plant density and competition for water, and thus limits vegetative growth supports increasing grain growth and wheat productivity.

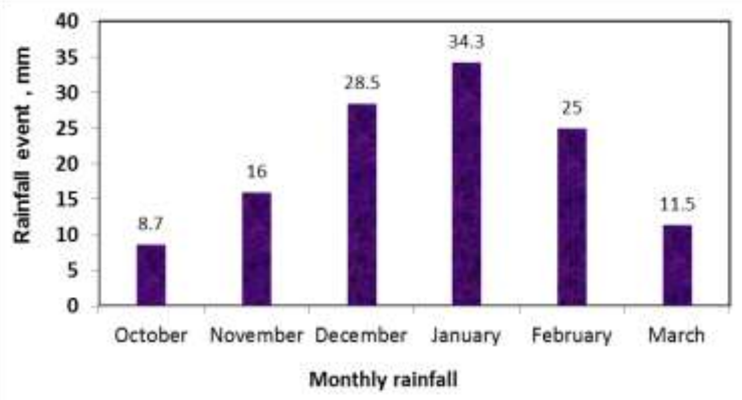


Fig (3): Rainfall data

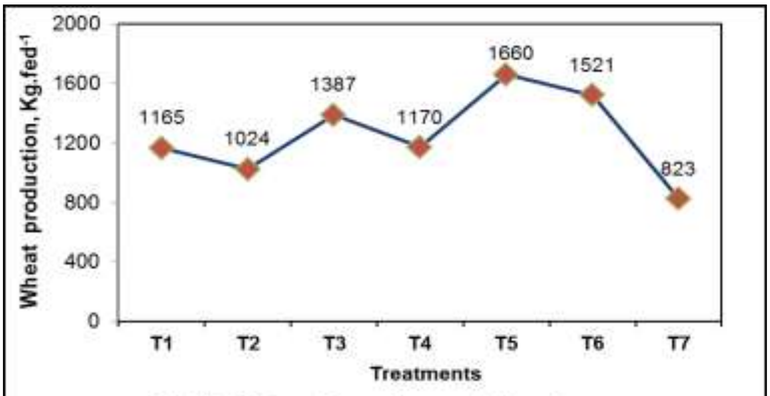


Fig (4) : Effect of supplemental irrigation treatments on average wheat yield production

Water Use Efficiency (WUE)

Effect of different treatments on water use efficiency (WUE) are shown in **Fig(5).** WUE reached to the lowest value of 1.58 $kg.m^{-3}$ under rain-fed condition as a control treatment .The values of WUE ranged from 1.85 to 2.83 $kg.m^{-3}$ with different amount of supplemental irrigation and seeding rate. Treatment (T5) achieved the highest value of 2.83 $kg.m^{-3}$ with seeding rate 48 $Kg.fed^{-1}$ and adding 65 m^3 of water as supplemental irrigation. The effect of supplemental irrigation water applied on WUE was observed, when treatment (T5 ,T6) > (T3,T4) > (T1,T2) with amount of water 65 , 50 and 35 $m^3.fed^{-1}$ respectively. Also, WUE was related to the seeding rate , treatment T5 ,T6 which used seeding rate 48 and 72 $Kg.fed^{-1}$ and applied the same amount of water 65 $m^3.fed^{-1}$ achieved difference values of WUE , 2.83 and 2.63 $kg.m^{-3}$. In generally availability of an alternative water source under the of rain-fed conditions, such as supplementary irrigation, that supports crop productivity, especially in critical conditions of drought wheat grain productivity. Supplemental irrigation increases soil moisture and reduces plant stress for thirst, which helps to fill wheat grains in the filling period, increases their weight and increases productivity. Using limited amount of water as a supplemental irrigation can improve both the crop productivity and increase water use efficiency, **(Man *et al.*, 2016).** WUE can be enhanced by improving the timing and amount of water application during the growing season, **(Dabach *et al.*, 2013)**. **Xu *et al.* (2016)** reported that the highest WUE was observed in the limited-irrigation. Therefore, the paramount importance of the water drop is manifested in maximizing the water use efficiency and increasing wheat grain productivity.

Water Use Productivity (WUP)

Data in **Fig(6)** illustrate the effect of different treatments on water use productivity (WUP).The values of WUP ranged from 6.64 to 11.90 $kg.fed^{-1}.mm^{-1}$ under different treatments. All treatments of supplemental irrigation recorded the optimum values compared to rain-fed treatment, values of WUP was varied according to the amount of water applied and seeding rate.T5 and T6 which applied 65$m^3.fed^{-1}$recorded the highest of 11.90 and 10.91 $kg.fed^{-1}.mm^{-1}$ with seeding rate 48 and 72$kg.fed^{-1}$ respectively. While T7 recorded the lowest value of 6.64 $kg.fed^{-1}.mm^{-1}$ under rain-fed conditions. In generally, increasing the amount of supplemental irrigation water applied and decreasing seeding rate increased WUP so (T5) > (T3)> (T1) and (T6) > (T4) > (T2). Improving water use productivity was related to the crop production and amount of water applied, under rain-fed condition wheat crop expose to insufficient water which induce drought and poor productivity. Applying supplemental irrigation system as alternative water source in rainless period helps to fill wheat grains in the filling period, increases their weight and sequence maximize crop yield production and water use productivity.

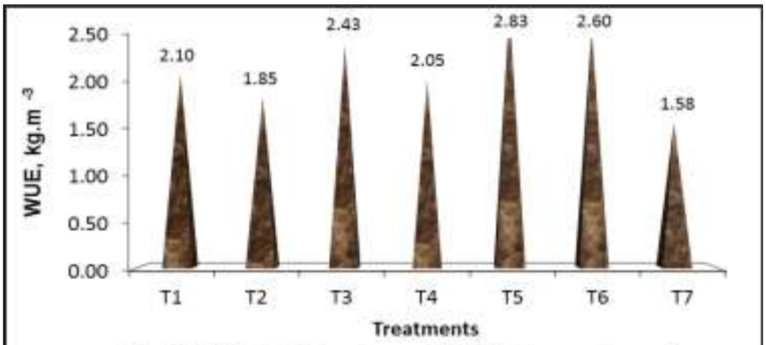


Fig (5): Effect of Supplemental irrigation and seeding rate on water use efficiency.

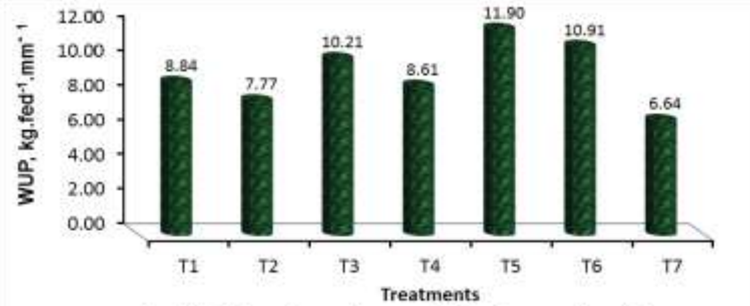


Fig (6): Effect of supplemental irrigation and seeding rate treatments on water use productivity

Economic Water Use Productivity, (EWUP).

Data in **Fig(7)** released the effect of applied supplemental irrigation as an additional water resource besides the rai-fed irrigation on the economic water use productivity,(EWUP) per Egyptian pound/m^3 (EGP/m^3) and according to the price of one tan of wheat grain in year 2022 which reached to 7000 pound. The values of EWUP ranged from 11.08 to 16.25 EGP/m^3 and varied under different treatments according to the amount of water applied and seeding rate.T5 and T6 which applied 65m^3.fed^{-1} with total 195m^3.fed^{-1} through three irrigations recorded the highest of 16.25 and 14.89 EGP/m^3 with seeding rate 48 and 72kg.fed^{-1} respectively. While T7 recorded the lowest value of 11.08 EGP/m^3 under rain-fed conditions. In generally, increasing the amount of supplemental irrigation water applied and decreasing seeding rate increased EWUP so (T5) > (T3)> (T1) and (T6) > (T4) > (T2). EWUP was related to the crop production and amount of water applied, applying supplemental irrigation system as alternative water source in rainless period helps to fill wheat grains in the filling period, increases their weight and sequence maximize crop yield and EWUP.

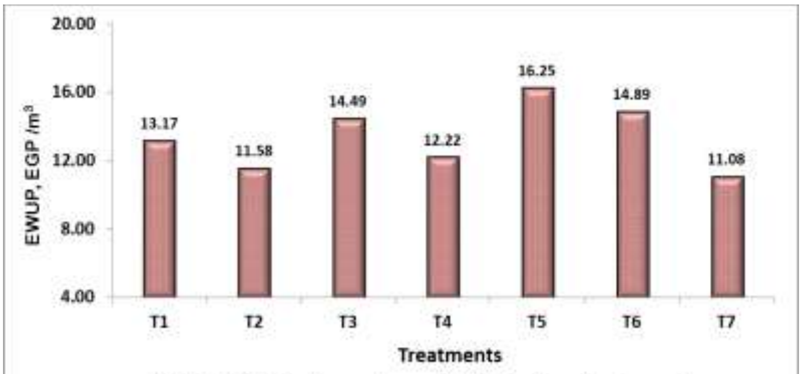


Fig (7) : Effect of supplementall irrigation treatments on (EWUP),economic water use productivity

CONCLUSION

Under rain-fed conditions in the arid and semi-arid region wheat supplemental irrigation was applied as an additional water resource with differences rates and seeding amount in the critical period of filling seeds stage and rainless period to maximize the wheat productivity to confront the climate changes and water scarcity. Results illustrated that sprinkler supplemental irrigation at rate of 65% of full irrigation with seeding rate of 48 $kg.fed^{-1}$ achieved the highest value of 1660 $kg.fed^{-1}$, 2.83 $kg.m^{-3}$ and 11.90 $kg.fed^{-1}.mm^{-1}$ as a productivity , WUE and WUP respectively. While T7 which depended on only rain-fed recorded the lowest values. In generally, decreasing seeding rate and increasing water applied of supplemental irrigation rate is considered one of the optimum practices for improving wheat productivity under rain-fed conditions .

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تقييم نظام الري بالرش كرى تكميلي لإنتاج محصول القمح تحت الظروف المطرية بشمال سيناء – مصر

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نظرا للجفاف وندرة المياه الذى يعتبر احد معوقات التنمية بالمناطق التي تعتمد على الزراعات المطرية ومياه الامطار فقط – وفى ضوء تعرض محصول القمح لنقص المياه بعد توقف المطر خاصة في الفترة الحرجة اثناء تكوين وأمتلأ الحبوب لذلك يهدف هذا البحث الى زيادة انتاجية القمح بإضافة مياه الري التكميلي للقمح في فترته الحرجة من توقف هطول المطر والاستفادة القصوى من مياه الري كمصدر إضافي للمياه من خلال نظام الري بالرش التكميلي لرفع كفاءة وحدة المياه المستخدمة وتعظيم الانتاجية. تم تطبيق التجربة بأحد المزارع الخاصة بمدينة العريش بمحافظة شمال سيناء خلال الموسم الشتوي 2021/2020. أجريت الدراسة لتحديد أثر نظام الري التكميلي بالرش ومعدلات التقاوي المستخدمة على تعظيم انتاجية القمح وكفاءة استخدام المياه في ظل ظروف ندرة المياه وتحديات التغيرات المناخية ، تم تطبيق المعاملات الاتية : معاملات الري التكميلي وهى نسبة معدلات الري من الري اليومي الكامل (33% – 50% – 65%) مقارنة بالنظام التقليدي المعتمد على المطر (بدون ري إضافي)، تم استخدام معدلين من التقاوي للزراعة :(48 كجم/فدان ،60 كجم/فدان). اظهرت النتائج أن استخدام الري التكميلي بمقدار 65% من الاحتياجات المائية الفعلية مع معدلات تقاوى 48 كجم/فدان حقق اعلى انتاجية لمحصول القمح بمقدار 1660 كجم/فدان ناتجا عن أعلى كفاءة لاستخدام المياه والتي كانت 2.83 كجم/ متر مكعب مياه وأعلى انتاجية للماء بمقدار 11.90 كجم/ فدان/ مليمتر مياه وذلك مقارنة بالمعاملات الاخرى.