7

Egypt. J. Agron. **Vol. 47**, No. 1, pp: 95 -106 (2025)

Egyptian Journal of Agronomy

http://agro.journals.ekb.eg/

Effect of Some Soil Amendments on Nutrients Uptake and Productivity of Cowpea/Maize Intercropping System under Water Stress in Sandy Soil

Ahmed, M. Mohamed Abd-Allah[1], **Rehab H. Hegab***[2] and **Amira Attia Elmehy**[1]

[1] *Crop Intensification Research Department, Field Crops Research Institute, Agricultural Research Center, Giza, Egypt*

[2] *Soil Fertility and Plant Nutrition, Desert Research Center, Egypt*

A FIELD experiment was conducted at the Ismailia Agricultural Research Station (ARC) in Egypt. To study the effect of three irrigation frequencies [2, 3 and 4 days], four soil application treatments [SN1 (100% NPK+ hydrogel), SN2 (75% NPK+ hyd.), SN3 (50% NPK+ hyd.), and SN4 (100% NPK without hydrogel as control)] on yields, nutrients content and uptake, land equivalent ratio (LER) and economic return of maize and cowpea. Maize components and maximum grain production as well as content and uptake of NPK were obtained with irrigation events once every 2 days (IF1) plus SN1, followed by irrigation once every 3 days (IF2) plus SN1. Also, the two most frequent irrigation frequencies (IF1 and IF2) plus SN2 improved the number of branches each plant and the yield of fresh fodder, with maximum values obtained by IF2. The NPK content, and NPK-uptake exhibited a similar forage yield trend. In contrast, the lowest values of all studied traits of both crops were obtained by less irrigation frequency (IF3) plus untreated soil with hydrogel (SN4). The highest LER (1.51) obtained by IF1x SN1 treatment, which at par with treatment IF2 x SN1 (1.50). Whereas highest values of net return was obtained with IF2 x SN1 compared to the other treatments. Thus, we can implement the irrigation maize/cowpea intercropping system once every 3 days with SN1(100% NPK +hydrogel) to reduce water frequency from 2 to 3 days and obtain higher productivity, nutrient content, LER, and maximum net income from intercropping maize and cowpea.

Keywords: Irrigation frequencies, Hydrogel, NPK content, NPK uptake, Economic return.

Introduction

Sand soil is considered a key agricultural challenge for food security in dry regions since it is a poor plant growth medium. It is distinguished by their low capacity to retain nutrients and water as a result of high deep percolation losses, which lower plant productivity (Wei and Durian, 2014). Thus, the application of soil amendments such as hydrogel in conjunction with irrigation frequency management to improve the efficiency of water and nutrient use will become increasingly crucial, particularly in light of the anticipated decrease in Egypt's share of Nile water due to climate change and increased water scarcity.

Hydrogel has the ability to absorb water more than 400 times its own weight. As the environment starts to dry out, the hydrogel progressively releases up to 95% of the water it has held, and it will rehydrate and repeat the process of storing water, when exposed to water again (Kalhapure et al., 2016). According to Saini and Malve (2023), the application of water-holding additives, such as hydrogel polymer, improved the efficiency of the use of water and nutrients, and it will become increasingly significant over time, particularly in arid and semiarid areas. Furthermore, the addition of hydrogels enhanced the physico-hydro characteristics of the soil by enhancing soil aggregation, porosity, and water retention (Abdallah, 2019). It has been proposed that using hydrogel to amend soil can improve water efficiency (Nirmala and Guvvali, 2019; El Shahawy et al., 2020) and decrease irrigation frequency (Kumar et al., 2018; Ali and Abdel-Aal, 2021). Furthermore, it has been discovered that the use of hydrogels increases plant growth and productivity (Ovalesha et al., 2017). Marashi and Mombani (2020), the utilisation of highly absorbent hydrogels has the potential to enhance the yield of cowpeas and mitigate the adverse effects of drought. Application of hydrogel has been found to have a financial advantage and may be a viable substitute for improving photosynthetic efficiency, assimilate partitioning, and growth and productivity under reduced irrigation conditions (Lotfi et al., 2018 and Shankarappa et al., 2020).

Additionally, implementing agronomic methods like intercropping systems can encourage water

*Corresponding author email: drrehabhh@yahoo.com
Received: 24/10/2024; Accepted 12/11/2024
DOI: 10.21608/AGRO.2024.330983.1544

conservation and raise the potential yield of sandy soils. A study conducted by Ghanbari et al. (2010) found that when maize is intercropped with cowpea, there is an improvement in soil moisture conservation, a decrease in water evaporation, and an increase in light interception during the intercrops compared with maize alone. Likewise, cowpea intercropping demonstrated greater values of transpiration, photosynthesis, and leaf water potential than cowpea alone (Lima Filho, 2000). According (Dhakal et al., 2016)., intercropping cowpea with maize increases soil organic matter, which reduces soil disintegration and increases the availability of water and nutrients. Additionally, because of their large leaf area and early foliage cover, legumes have been shown to conserve water to a significant degree. Intercropping cereal with legumes increases system productivity and improves soil health while offering more opportunities to reduce the negative effects of moisture stress (Layek et al., 2018). El-Mehy et al., (2020) showed that intercropping culture led to a 22% reduction in the amount of water used for irrigation, with marginal yield losses during irrigation every 4 days compared to 3 and 5 days. The impact of hydrogel treatment on soil characteristics and water conservation has been investigated by numerous researchers in Egypt. However, little research was conducted to determine how these substances will affect irrigation water savings with intercropping systems in field conditions. Consequently, this experiment's goal was to investigate the effects of varying irrigation frequency in the presence of hydrogel on yields, nutritional content, competitive dynamics, and economics of cowpea and maize intercropped in sandy soil.

Materials and Methods

Experimental site and conditions

During the summer season of 2021 &2022, a field study was conducted at the Ismailia Agricultural Research Station in Egypt to examine the effects of three different irrigation frequencies and soil application treatments on the yields, nutrient content, land use, and economic return of a cowpea intercropped with maize system. This area has an arid environment with little rainfall. Before planting, soil samples were collected from soil layers using Chapman and Pratt's (1961) conventional procedure to determine a physical and chemical characteristics of the experimental field. as indicated in Table 1. In the two growing seasons, the previous crop was wheat.

Experimental design and treatments

A randomized complete block design in strip-plot with three replicates was used. Irrigation frequency as first factor and soil applications (incorporation of inorganic NPK with hydrogel, beside control) as second factor, were distributed in the vertical and horizontal stripes, respectively. The experimental plot was 10.5 m^2 and had 5 ridges, each measuring 3.0 m in length and 3.5 m in width. Plots were placed 1.5 meters apart to prevent interference.

Experimental treatments were as follows:

I- Irrigation frequency treatments were irrigation once every 2, 3 and 4 days, namely IF_1, IF_2 and IF_3, respectively. Irrigation treatments start after 30 days of sowing by using sprinkler irrigation.

II- Soil applications were as following:

1- Incorporation of inorganic 100% NPK (recommended dose, RD) with hydrogel (SN1).

2- Incorporation of inorganic 75% NPK of RD with hydrogel (SN2).

3- Incorporation of inorganic 50% NPK of RD with hydrogel (SN3).

4- Control, 100% NPK without hydrogel (SN4).

Table 1. Physical and Chemical analysis of the experimental soil.

Soil depth (cm)	**Physical analysis**									
	Particle size distribution (%)			**Texture Class**	**BD (mg m^{-3})**	**FC (%)**	**PWP (%)**	**AW (%)**		
	Sand	**Silt**	**Clay**							
0-20	94.10	3.20	2.70		1.63	12.80	3.60	9.20		
20-40	95.50	2.60	1.90	Sandy	1.72	11.25	2.90	8.35		
40-60	96.00	2.45	1.55		1.70	7.40	2.10	5.30		
Soil depth (cm)	**Chemical analysis**									
	pH (1:2.5)	**EC (dS m^{-1})**	**Soluble cations (meq l^{-1})**				**Soluble anions (meq l^{-1})**			
			Ca^{2+}	**Mg^{2+}**	**Na^+**	**K^+**	**CO_3^{2-}**	**HCO_3^-**	**Cl^-**	**SO_4^{2-}**
0-20	7.60	0.60	2.75	1.32	1.34	0.59	-	2.10	2.72	1.18
20-40	7.45	0.54	2.30	1.20	1.35	0.55	-	2.08	2.73	0.59
40-60	7.35	0.52	2.08	1.13	1.42	0.57	-	2.07	2.75	0.38
Available nutrients (mg kg^{-1})				**N**		P			K	
				15.25		4.56			53.18	

BD: Bulk density, FC: Field capacity, PWP: Permanent wilting point, AW: Available water, pH at 1: 2.5, EC: soil pest.

Table 2. Irrigations number, irrigation time and applied irrigation water for each irrigation frequency (IF).

IF	Month	Irrigations No.	Time (hr/fed)	Applied water m^3/fed	Total/ season (m^3/fed)	Irrigations No.	Time (hr/fed)	Applied water m^3/fed	Total/ season (m^3/fed)
		2021 season				2022 season			
IF1	1^{st}	15	1.5	587.2	3197.3	15	1.5	587.2	3226.0
	2^{nd}	15	2.0	783.0		15	2.0	783.0	
	3^{th}	16	2.5	1044.0		15	2.5	978.8	
	4^{th}	15	2.0	783.0		16	2.1	877.0	
IF2	1^{st}	15	1.5	587.25	2349.0	15	1.5	587.2	2365.1
	2^{nd}	10	2.0	522.0		10	2.0	522.5	
	3^{th}	11	2.5	717.8		10	2.5	6522.0	
	4^{th}	10	2.0	522.0		11	2.1	602.9	
IF3	1^{st}	15	1.5	587.2	1892.3	15	1.5	587.2	1965.3
	2^{nd}	8	2.0	417.6		8	2.0	417.6	
	3^{th}	8	2.5	522.0		8	2.5	522.0	
	4^{th}	7	2.0	365.4		8	2.1	438.5	

IF1: watering each 2 days, IF2: watering each 3 days, IF3: watering each 4 days

These findings suggest that Moringa oleifera IF1: watering each 2 days, IF2: watering each 3 days, IF3: watering each 4 days

The crops were irrigated using a solid-set sprinkler irrigation system with 29 sprinklers per feed and rotating RC160 sprinklers with a 0.90 m³/hr discharge rate at 2.80 bars nozzle pressure.

Description and application of Hydrogel

Hydrogel is a polymer composite made by Lucky Star TG., (French) that contains 40% hydro polymer, 6.5% nitrogen, 4.8% phosphorus, 8.2% potassium, and a storage capacity of 300–500%. It also contains cytokinin, amino acids, peptides, and various vitamins. Hydrogel was mixed with fine dry soil in a 1:10 ratio and broadcast during planting in the row below seeds, followed by planting at a rate of 15 kgfed^{-1}.

Agronomic practices

In the 2021 and 2022 growing seasons, the local cowpea variety was planted on May 15th and May 17th, 10 days later, maize hybrid Giza 168 was planted on May 25th and 27th, respectively. One plant per hill was left after maize seeds were sown on one side of the ridge (70 cm broad) in hills 25 cm apart, in both sole and intercropping systems. On the other side of the corn ridge, cowpea seeds were planted 20 cm apart, resulting in two plants per hill (100% maize and 50% cowpea) in the intercropping planting. When planting alone, two plants were left per hill on both sides of the ridge, spaced 20 cm apart. Before planting cowpea, seeds was coated with N-fixer okadeen (*Rhizobium melitota*). The first cut of cowpea was harvested on July 18th and 20th, and the second cut was harvested in the first week of September, and maize was harvested on September 20th and 22nd in the corresponding years 2021 and 2022. The economic returns and competitive relationships of intercropping were calculated in comparison to sole cultivation.

Mineral fertilizers of P and K were given to the soil at the following rates: 100, 150, and 200 kg fed $^{-1}$of calcium superphosphate (15.5% P_2O_5) and 25, 33, and 50 kg fed^{-1}of potassium sulfate (48% K_2O), which correspond to 50, 75, and 100% of PK recommended. Mineral nitrogen fertilization of maize was applied at a rate of 60, 90, and 120 kg N/fed. The following was how it was used: Ammonia sulfate (20.6% N) at a rate of 100 kg/fed when planting maize. A month later, the remaining N was added as ammonium nitrate (33.5% N) in four equal doses every ten days. For cowpea, ammonia sulfate (20.6% N) was added at planting as a boosting dose at a rate of 20 kg N/fed. Both crops were grown using standard and consistent agronomic procedures.

Parameter assessments

Maize traits: Following physiological maturity, ten plants chosen at random from each subplot were taken out in order to measure the ear length, ear diameter, weight of grains per ear, and 100-grain weight. After being corrected to a 15.5% moisture content on a per subplot basis, Grain yield kg/fed was measured and changed to ardab/fed (140 kg).

Cowpea traits: The number of branches on each plant and the yield of fresh forage (ton/fed) of the first and second cuttings as well total cuts.

Content and uptake of nutrients in grain maize and forage cowpea

In accordance with A.O.A.C. (1990), the nitrogen concentration (%) was measured using the microkjeldahl method. phosphorus (P%) was calculated by colorimetric analysis with ascorbic acid, as described by Frei et al. (1964). Using a flame photometer, potassium (K%) was calculated (Chapman and Pratt 1961). Thereafter, nutrient uptake was computed as follows:

Nutrients uptake per unit area (kg/fed) = Yield of grain maize or forage cowpea per unit area (kg/fed) x nutrients content (NPK %).

Competitive relationships

Land equivalent ratio (LER)

LER is the ratio of area required for intercropping at the same level of management that is required for

sole planting in order to get an equivalent yield (Willey, 1979). It is computed as follows: LER= (Yab/Yaa) + (Yba/Ybb)
where Yaa= sole planting yield of maize, Ybb= sole planting yield of cowpea, Yab= intercrop yield of maize and Yba= intercrop yield of cowpea.

Economic evaluation

Gross return of intercropping planting= Price of maize yield + price of cowpea yield (L.E.).
Net return/fed= Gross return - (fixed costs of maize + variable costs of cowpea) based on the Bulletin of Statistical Cost Production and Net Return's grain maize prices for 2021 and 2022, while cowpea forage production costs are based on the two-season farm cost. Cowpeas were 463 and 475 L.E. per ton, whereas an ardab of maize grains cost 659 and 745 L.E.

Statistical analysis

An analysis of variance (ANOVA) was performed on all measurements in this study using MSTAT-C software (Freed, 1991). At 0.05 probability levels, a least significant difference (LSD) test was used to compare the treatment means.

Results and Discussion

Maize characters

Effect of irrigation frequencies on yield and its components

Yield components of maize (Ear diameter, length, and weight of grains/ ear, 100-grain weight, and grain yield fed^{-1} were significantly affected by irrigation frequency in the two growing seasons (Table 3). The greatest components of yield and grain yield fed^{-1} were obtained with irrigation events once every 2 days (IF1), followed by irrigation once every 3 days (IF2). Irrigation treatment IF2 was statically at par with IF1 in these traits. The irrigation frequency IF3 (irrigation once every 4 days) resulted in decreases in ear length of 10.9 and 6.4 %, ear diameter by 10.6 and 8.8%, grains weight ear^{-1} of 13.5 and 9.2%, 100-grain weight of 11.8 and 8.5% and grain yield fed^{-1} of 11.2 and 8.1 %, respectively, when compared with the IF1 and IF2 treatments, averaged over the two seasons. Low irrigation frequency can lead to water stress, particularly in sandy soils, and is correlated with unreasonably lengthy irrigation intervals. This is the reason of yield and yield components reduction. In this regard, numerous studies discovered that subjecting maize plants to drought stress by extending the time between irrigations resulted in a reduction in the length and diameter of the ears (Yasin, 2016), the 100-grain weight (Abo-Marzoka et al., 2016), the grain weight ear^{-1} (El-Sobky and Desoky, 2017 and Farouk et al., 2018), and the grain yield fed-1 (Ali and Abdelaal, 2020). Since water is necessary for many physiological processes, including the uptake of nutrients, a reduction in water absorption causes growth retardation and a decrease in yield (Irmadamayanti et al., 2021). According to Zhang et al. (2019), a suitable irrigation interval increased the production of maize by lowering soil-water evaporation and ETc, preserved a high level of soil moisture storage in the top soil layer and facilitated an environment that encouraged maize development.

Effect of soil applications on yield and its components

Yield components and grain yield fed-1 were likewise significantly impacted by the soil treatments, independent of watering frequency. With the exception of ear diameter. Amending the soil with hydrogel, irrespective of NPK level, resulted in higher values of all studied characters than untreated soil (SN4). Applied SN1 (100%NPK+ hyd.) recorded the highest yield and component values, followed by SN2 (75%NPK+hyd.). Mean for the two seasons, decreases in yield and its components for SN4 relative to SN1 and SN2 were 20.7 and 9.3% for grains weight ear^{-1}, and 19.8 and 11.1% for grain yield fed^{-1}, respectively (Table 3). The addition of hydrogel enhanced the capacity of porous soils to hold water, delaying the onset of permanent wilting percentages under conditions of high evaporation. Agaba et al. (2011) and Ali and Abdel-Aal (2021) found that a hydrogel increased water-holding capacity led to a considerable decrease in the frequency of irrigation. According to Yaseen et al. (2020), combining exopolysaccharides (EPS) with superabsorbent polymer may increase the drought tolerance of maize plants.

Interaction effect on yield and its components. In both seasons, ear grain weight and grain yield fed-1 were significantly impacted by the combination of soil application and irrigation frequency (Table 3). The highest values of the previous traits were produced with IF1x SN1, followed by IF2 with SN1. However, the lowest values were recorded by control (SN4) and the lower irrigation frequency (IF3). Maize plant roots clumping together around hydrogel pieces give the roots long-term access to water, which helps meet the plants' needs for photosynthesis and nutrient intake. These results are in line with those of (Ovalesha et al., 2017 and Ali and Abdel-Aal 2021)

Effect of irrigation frequencies on nutrients content and uptake of maize

Results in Table 4 show the effect of irrigation frequency, soil applications, and their interaction on nutrient content and uptake (kg fed^{-1}). Concerning the effect of irrigation frequency, results reveal that maize grain content and uptake of NPK were significantly affected by different irrigation frequencies. Irrigation once every 2 and 3 days did not show a significant difference in content and uptake of NPK. However, the difference in the previous traits became quite evident as the irrigation frequency increased from 2 to 4 days. This increasing of nutrient content and uptake under irrigation treatment (IF1 and IF2) may be credited with increasing the quantity of water used for irrigation, this increases the amount of nutrients absorbed by plants in comparison to stressed plants under IF3 (every 4 days). He and Dijkstra (2014) found that water stress affects the kinetics of nutrient uptake by roots and reduces mineralization and nutrient mass flow. Increasing drought levels led to a considerable decrease in nutrient uptake, as reported by El-Syed et al. (2023).

Effect of soil applications on nutrients content and uptake of maize

Significantly increase in NPK content and uptake by grain maize was recorded under treatment SN1 which remained at par with treatment SN2 compared to the rest of treatments (Table 4). Accordingly, the increases in N-uptake, P-uptake, and K-uptake were 36, 41, and 52 percent, respectively, with SN1 compared to SN4 (control). El-Syed et al. (2023), reported similar results, noting that nutrient absorption was greatly increased by amended soil with inorganic fertilizers as opposed to inorganic fertilizers alone. According to Albuquerque et al. (2022) the controlled release of nutrients was responsible for the beneficial effects of hydrogel + NPK.

Interaction of effect on nutrients content and uptake of maize

The interactive effect of irrigation frequency × soil applications had a noticeable impact on the earlier traits (Table 4). The treatment of IF1 plus SN1, followed by IF2 plus SN1, caused the highest contents of NPK, and NPK-uptake. These results might be due to the positive effect of hydrogel in reserving humidity in sandy soil for a longer time, which increases nutrient availability and uptake, consequently, causing better assimilation of nutrients in plants and improving plant nutritional status, furthermore, increasing K availability that stimulating metabolism activity. These results coincides with the study of Marashi and Momban (2020) who reported that super absorbents increased grain yield due to the availability of water and nutrients. though, the treatment of IF3 plus SN4 caused the lowest nutrient content and uptake. This demonstrated that water is more important than fertilizer for the absorption and transportation of nutrients. The availability of water, rather than nutrients, maybe the main reason for decreased plant growth with greater drought stress (He and Dijkstra, 2014). The wide canopy structure of maize makes it more vulnerable to water stress than other crops, despite the fact that it uses water efficiently (Huang et al., 2006). These findings agree with Solanki et al., (2021) on acid lime, who found that applying hydrogel to the soil enhances nutrient retention in sandy soil.

Table 3. Influence of irrigation frequencies, soil applications, and their interactions on maize characters in the two seasons.

Traits		Ear length (cm)		Ear diameter (cm)		Grain wt. ear^{-1} (g)		100-grain wt. (g)		Grain yield (ardab fed^{-1})	
treatment		S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
Irrigation frequencies (IF)											
IF1		21.02	20.38	4.49	4.47	122.59	117.00	25.57	25.09	18.86	18.57
IF2		19.92	19.49	4.40	4.25	116.00	112.17	24.79	24.39	18.26	17.94
IF3		18.51	18.36	4.12	3.83	104.17	102.92	23.03	21.92	16.67	16.48
LSD 0.05		1.54	1.48	0.21	0.27	9.11	8.48	0.83	0.67	0.80	0.85
Soil applications (SN)											
SN1		22.23	21.19	4.68	4.58	134.45	127.67	25.30	24.59	20.26	19.94
SN2		20.31	20.33	4.47	4.26	115.11	111.00	24.82	24.01	18.62	18.27
SN3		18.52	18.38	4.14	3.98	104.00	102.56	23.85	23.41	16.47	16.29
SN4 (control)		18.19	17.75	4.06	3.90	103.44	101.55	23.87	23.26	16.35	16.16
LSD 0.05		1.29	1.32	N.S	N.S	6.99	6.72	0.74	1.10	0.79	0.70
interaction											
IF1	SN1	23.63	22.27	5.05	5.09	140.67	132.67	26.40	25.70	20.93	20.24
	SN2	21.63	21.67	4.64	4.40	121.67	115.33	26.03	25.27	19.28	18.85
	SN3	18.93	18.00	4.10	4.14	110.00	104.33	24.23	24.40	16.92	17.10
	SN4	19.87	19.60	4.17	4.24	118.00	115.67	25.60	25.00	18.30	18.19
IF2	SN1	22.07	21.57	4.59	4.52	139.00	129.67	25.73	25.33	20.81	20.00
	SN2	20.70	20.30	4.45	4.34	117.33	112.33	25.10	24.67	18.86	18.96
	SN3	19.00	19.03	4.27	4.07	105.67	106.67	24.33	24.00	16.87	16.50
	SN4	17.90	17.07	4.25	4.06	102.00	100.00	24.00	23.77	16.50	16.30
IF3	SN1	21.00	19.73	4.39	4.13	123.67	120.67	23.77	22.73	19.71	19.68
	SN2	18.60	19.03	4.30	4.05	106.33	105.33	23.33	22.10	17.07	17.00
	SN3	17.63	18.10	4.06	3.73	96.33	96.67	22.70	21.83	15.63	15.27
	SN4	16.80	16.57	3.76	3.40	90.33	89.00	22.3	21.00	14.25	13.98
LSD 0.05		NS	NS	NS	NS	6.49	5.72	NS	NS	1.75	0.82
Sole maize		20.55	19.89	4.56	4.36	132.50	128.93	25.60	25.02	21.98	21.35

IF1: watering each 2 days, IF2: watering each 3 days, IF3: watering each 4 days, SN1:100 % NPK + hydrogel, SN2:75 % NPK + hydrogel, SN3: 50 % NPK + hydrogel, and SN4:100% NPK without hydrogel (control).

Table 4. Influence of irrigation frequencies, soil applications, and their interactions on maize grain content of NPK and uptake in the two seasons.

		N %		P %		K %		Uptake N (kg/fed)		Uptake P (kg/fed)		Uptake K (kg/fed)	
		S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
Irrigation frequencies (IF)													
2 days		1.59	1.61	0.42	0.47	0.65	0.68	42.13	41.89	11.15	12.24	17.39	17.90
3 days		1.49	1.52	0.38	0.44	0.59	0.60	38.14	38.40	9.91	11.12	15.42	15.29
4 days		1.35	1.36	0.34	0.37	0.48	0.50	31.68	31.63	8.02	8.75	11.44	11.63
LSD 0.05		0.12	0.11	0.14	0.12	0.13	0.11	3.56	3.86	2.71	2.98	3.99	3.39
Soil applications (SN)													
SN1		1.59	1.55	0.40	0.46	0.66	0.68	45.53	43.42	11.62	12.93	18.85	19.05
SN2		1.54	1.52	0.40	0.44	0.61	0.61	39.61	39.13	10.39	11.28	15.84	15.59
SN3		1.39	1.46	0.37	0.41	0.51	0.55	32.03	33.37	8.55	9.40	11.90	12.58
Control		1.39	1.46	0.35	0.40	0.53	0.54	32.09	33.31	8.20	9.20	12.42	12.54
LSD 0.05		N.S	N.S	0.12	0.10	0.09	0.06	6.23	5.15	2.46	2.56	4.70	4.12
interaction													
IF1	SN1	1.75	1.63	0.43	0.49	0.71	0.76	51.07	46.13	12.75	13.83	20.59	21.77
	SN2	1.64	1.61	0.43	0.47	0.67	0.69	44.17	42.56	11.64	12.42	18.10	18.29
	SN3	1.42	1.56	0.40	0.45	0.57	0.61	33.35	37.47	9.71	10.80	13.79	14.59
	Con	1.56	1.62	0.41	0.47	0.67	0.66	39.93	41.41	10.50	11.90	17.08	16.95
IF2	SN1	1.57	1.55	0.42	0.46	0.67	0.69	45.23	43.45	12.22	12.82	19.82	19.38
	SN2	1.56	1.55	0.41	0.45	0.64	0.61	41.16	41.23	10.81	12.00	17.00	16.33
	SN3	1.43	1.50	0.36	0.43	0.53	0.55	33.70	34.70	8.57	10.09	12.71	12.74
	Con	1.41	1.50	0.35	0.42	0.52	0.56	32.46	34.21	8.02	9.56	12.20	12.71
IF3	SN1	1.46	1.48	0.36	0.44	0.59	0.58	40.28	40.69	9.90	12.12	16.15	15.99
	SN2	1.40	1.41	0.37	0.40	0.52	0.51	33.52	33.58	8.72	9.43	12.43	12.16
	SN3	1.33	1.31	0.34	0.34	0.42	0.49	29.05	27.93	7.37	7.33	9.19	10.41
	Con	1.20	1.24	0.31	0.31	0.40	0.41	23.87	24.31	6.09	6.12	7.99	7.96
LSD 0.05		N.S	0.20	0.17	0.15	0.20	0.21	10.14	6.73	3.33	3.28	5.73	6.31

IF1: watering each 2 days, IF2: watering each 3 days, IF3: watering each 4 days . SN1:100 % NPK + hydrogel, SN2:75 % NPK + hydrogel, SN3: 50 % NPK + hydrogel, and SN4:100% NPK without hydrogel (control).

Cowpea characters

Effect of irrigation frequencies on forge yield

Results in Table 5 show that the studied characters of cowpea for first and second cuts were significantly affected by irrigation frequency, soil applications and their interaction in the two growing seasons. The two most frequent irrigation frequencies (IF1 and IF2) improved the number of branches plant^{-1} and fresh forage yields fed^{-1}, with maximum values obtained by IF2. While, irrigation frequency treatment IF3 decreased total fresh forage yields fed^{-1} by 9.0 and 16.7% in 2021 season, and by 6.2 and 13.5% in 2022 season compared to IF1 and IF2, respectively. This means that exposing cowpea plants to optimum soil moisture with irrigation frequency IF1 and IF2 encouraged branches plant^{-1} production may cause an increase in plant capacity of nutrients absorption, photosynthesis efficiency and consequently increased yield production. Optimum root zone aeration, improved nutrient utilization, and more effective use of soil water could be the cause of the higher yield in IF2 compared to IF1. In this respect, numerous investigations have discovered that sufficient watering of the soil increased the number of branches plant^{-1} and cowpea yield (Öktem, 2006 and Bala et al., 2021). According to Ehsas et al. (2018), irrigation every 20 days produced an alfalfa forage that produced the highest green forage production (26.80 t ha^{-1}) when compared to irrigation every 10 and 30 days.

Effect of soil applications on forage yield

Concerning soil applications. The number of plant branches and fresh feed yields fed^{-1} were increased significantly with the amended soil by hydrogel in combination with NPK fertilizer (Table 5). The highest values of the number of branches plant^{-1} and a fresh yield fed^{-1} of first, second and total cuts were observed with SN2 (75% NPK + hyd.) followed by SN1(100% NPK + hyd.). Whereas, SN4 treatment (100% NPK without hyd.) significantly reduced the number of branches plant^{-1}, as an average of the two cuts, by 13.8, 22.5 and 11.7% in 2021 and 15.3, 21.6 and 9.9% in 2022, and total fresh yields by 11.4, 16.6 and 7.1% in first season and 7.7, 12.4 and 5.7% in second season compared to SN1, SN2 and SN3, respectively. Hydrogel treatment may be a useful technique to promote plant growth in sandy soils by improving water retention and nutrient uptake, which in effect improves plant branching and yield. This result is in line with the findings of Abdallah (2019), who suggested that hydrogel-treated soil enhances the amount of water available and decreases plant stress. Applying hydrogel can increase cowpea yield (Marashi and Mombani, 2020) and decrease irrigation frequency (Kumar et al., 2018 and Ali and Abdel-Aal, 2021).

Interaction effect on forage yield

Interaction among irrigation frequencies and soil applications significantly affected number of branches plant^{-1} of the two cuts and forage yield fed^{-1} of 2nd cuts (in 2021 and 2022 season), Table 5. The highest branches number plant^{-1} and forage yields fed^{-1} of cowpea were produced by IF2 x SN2, followed by IF1x SN2 and IF2 x SN1 for branches plant^{-1} and fresh yields fed^{-1}, respectively. On contrary, the lowest values were recorded by the lower irrigation frequencies (IF3) under untreated soil (SN4). This indicates that amended soil with hydrogel reduces irrigation frequency due to increased water availability, which positively affects the number of branches/plant and biomass yield. When compared to the unamended soil, the soil moisture at field capacity rose by 400% with hydrogel, and at the wilting point (-15 bar), it was comparable to the unamended soil's field capacity (Montesano et al., 2015). The result coincides in the study of Marashi and Mombani (2020).

Effect of irrigation frequencies on nutrients content and uptake of forage cowpea

Irrigation frequency, soil applications and their interaction significantly affected NPK content and uptake of forage cowpea, as average of the two cuts, through the two growing seasons, as indicated by Table 6. The irrigation frequencies of 2 and 3 days did not show a significant difference in nutrients content and uptake. However, the difference in nutrients content and uptake detected with irrigation frequency of 4 days. The highest values observed with IF2, which meant that the shorter and medium irrigation frequency is optimum for cowpea plants and maintained soil moisture regime in the root zone closer to field capacity with no moisture stress. These findings concur with Geeth's (2019) findings. Compared to a growing water deficit from 100% to 80% of irrigation requirements fed-1, the cowpea seeds' nitrogen and potassium content increased, with no discernible changes between the two scheduling regimes that came before. According to Haque et al. (2020), cowpea have a yield response factor (Ky) of 0.98, which is less than unity, indicating that they are a drought-tolerant crop.

Effect of soil applications on nutrients content and uptake of forage cowpea

The same Table show that the NPK content, and NPK-uptake were statistically similar with SN1 and SN2 treatments, but significantly higher than SN3 and SN4. The increases in N, P, and K content being 23, 19, and 7 % and uptake of N, P and K were 44, 40 and 25 %, respectively, under SN2 compared to control (SN4), as average of two seasons. The superiority of SN2 over the rest of the treatments may be due to hydrogel partially replacing NPK fertilizers. NPK uptake were significantly ($P < 0.05$) improved following application of biochar as amended soil (Hiama et al., 2019). Also, the applied N fertilizer provides the cowpea plant with all the nitrogen it needs until biological N-fixing (BNF) begins. However, excessive N fertilizer application prevents BNF by causing inefficient nodules to form. Similar findings were reported by El-Mehy et al. (2023), who found that maize responded more strongly to N fertilizer than did dry beans.

Interaction of effect on nutrients content and uptake of forage cowpea

Significant effect of interaction was obtained of the two factors on nutrients content and uptake (Table 6). The highest values of these traits were observed with IF2 + SN2 and IF1 + SN1, without significant differences between them. Whereas the lowest values were obtained by IF3 plus SN4. Interpretation these results might be referred to the higher degree of water stress in IF3 + SN4 (untreated soil with hydrogel) Can result in low microbial activity and mineralization of nutrients. It is well known that a plant's ability to absorb nutrients depends on the nutrients that are present in the soil. The soil's physical and chemical characteristics affect the nutrients' availability for nutrient transformation. This study, the irrigation frequency of every 3 days plus SN2 maintained the optimal soil moisture regime, aeration and improve the microbial activity. Similar findings were obtained by Albuquerque et al. (2022), who concluded that the controlled release of nutrients and water retention accounted for the majority of the advantages of hydrogel +NPK. According to Fei et al. (2019), hydrogel's ability to alternate between nutrient releasers and nutrient adsorbents based on the concentration of nutrients in the surrounding environment allows it to adsorb large amounts of nutrients and mediate soil NPK retention.

Land equivalent ratio (LER)

The mean values of the LER ratios of irrigation frequency x soil nutrient treatments were clearly more than 1.0, as shown by the results in Table (7), suggesting that intercropping cowpea with maize yields benefits in terms of land usage. Additionally, the results suggest that the relative yield of maize (RYm) was consistently higher than the relative yield of cowpea (RYc), and that there was a positive correlation between relative yield and plant density per unit area (100% maize: 50% cowpea). The highest LER (1.53 and 1.49) obtained by IF1plus SN1 treatment, which at par with treatment IF2 plus SN1 (1.51 and 1.49) compared to the other treatments in 2021 and 2022 season, respectively. This confirms the potential of the hydrogel to reduce irrigation frequency from 2 to 3 days without significantly affecting the productivity of both crops. However, the smallest LER values (1.07 and 1.09) were obtained by less irrigation frequency with untreated soil with hydrogel (IF3 x SN4), in the first and second seasons, respectively. Decreasing irrigation frequency from 2 to 4 days results in increased water stress and reduced NPK-uptake, consequently reducing the relative yield of both crops. These results are in harmony with those obtained by Liu et al. (2021) hydrogel-integrated soil reduces water scarcity and irrigation frequency, controls soil nutrient release, and enhances plant growth in dry and semi-arid regions. The benefit of intercropping cowpea with maize was noted by numerous studies, Layek et al. (2018), who showed that intercropping legumes with cereals increases system productivity and soil health, while also offering more opportunities to reduce the negative effects of moisture stress. Legumes are known to conserve water to a significant degree because of their early foliage cover and larger leaf area, according to Dhakal et al. (2016).

An economic assessment

Gross and net return/fed

Results in Table 8 show that gross and net returns of the two intercropping components comparative with sole maize as the main crop. Incorporation of hydrogel with inorganic NPK at 100 or 75% gave gross and net return values higher than those of sole maize, irrespective of irrigation frequency, in both seasons. Total cost increased with high irrigation frequency and by intercropping cowpea. However, the greatest net return was 5013 and 5070 L.E fed^{-1} obtained by IF2 plus SN1, followed by IF1plus SN1in first season and IF2 plus SN2 in second one. While control treatment (SN4) with the less irrigation frequency (IF3) had the smallest net return., being 610 and 703 L.E. fed^{-1} in first and second season, respectively. This indicated that embedding hydrogel with NPK fertilizer can reduce irrigation frequency from two-days to three-days in sandy soil without negatively affect productivity and net return. Under conditions of low irrigation, the use of hydrogel can be a viable alternative to boost growth and production, and a financial benefit was noted (Lotfi et al., 2018 and Shankarappa et al., 2020). It is also evident that the net return of intercropping cowpea with maize and applied hydrogel outperformed sole maize, regardless of irrigation frequency. The greatest benefit of hydrogel +NPK was attributed to the controlled release of nutrients and water retention (Albuquerque et al., 2022).

Table 5. Influence of irrigation frequencies, soil applications, and their interactions on cowpea characters in the two seasons.

		No. of branches plant^{-1} of 1st cut		Yield of 1st cut (ton fed^{-1})		No. of branches plant^{-1} of 2nd cut		yield of 2nd cut (ton fed^{-1})		Total Yield (ton fed^{-1})	
		S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
Irrigation frequencies (IF)											
2 days		4.67	4.79	3.866	3.583	2.73	2.58	1.462	1.364	5.328	4.947
3 days		4.97	4.93	4.153	3.883	2.97	2.48	1.667	1.476	5.820	5.360
4 days		4.36	4.01	3.449	3.280	2.59	2.20	1.299	1.235	4.747	4.514
LSD 0.05		0.15	0.19	0.248	0.193	0.11	0.15	0.045	0.066	0.246	0.187
Soil applications (SN)											
SN1		4.90	4.78	3.922	3.639	2.94	2.55	1.601	1.399	5.523	5.038
SN2		5.16	5.01	4.049	3.807	3.16	2.73	1.701	1.500	5.750	5.307
SN3		4.50	4.34	3.738	3.438	2.57	2.42	1.381	1.348	5.119	4.786
Control		4.10	4.18	3.581	3.444	2.39	1.97	1.221	1.185	4.802	4.629
LSD 0.05		0.17	0.30	0.178	0.200	0.14	0.13	0.028	0.080	0.191	0.162
interaction											
IF1	SN1	4.73	4.97	4.037	3.639	3.03	2.80	1.588	1.459	5.626	5.098
	SN2	5.20	5.17	4.167	3.860	3.20	2.86	1.820	1.553	5.987	5.412
	SN3	4.27	4.63	3.827	3.468	2.60	2.67	1.327	1.308	5.153	4.776
	Con.	4.47	4.40	3.432	3.364	2.10	1.97	1.113	1.134	4.546	4.499
IF2	SN1	5.13	5.07	4.213	3.992	3.17	2.57	1.747	1.548	5.959	5.541
	SN2	5.37	5.43	4.395	4.099	3.37	2.83	1.902	1.697	6.297	5.796
	SN3	4.73	4.60	4.031	3.627	2.70	2.37	1.623	1.403	5.654	5.029
	Con.	4.63	4.63	3.974	3.815	2.63	2.13	1.395	1.257	5.369	5.072
IF3	SN1	4.83	4.30	3.517	3.287	2.63	2.27	1.467	1.190	4.984	4.477
	SN2	4.90	4.43	3.585	3.463	2.90	2.5	1.380	1.250	4.965	4.713
	SN3	4.50	3.80	3.357	3.218	2.40	2.23	1.193	1.334	4.55	4.552
	Con.	3.20	3.50	3.336	3.152	2.43	1.8	1.155	1.164	4.491	4.316
LSD 0.05		0.39	N.S	N.S	0.281	0.15	0.16	0.050	0.150	N.S	0.245
Sole		4.47	4.76	6.800	6.590	2.75	2.53	3.460	3.340	10.26	9.93

IF1: watering each 2 days, IF2: watering each 3 days, IF3: watering each 4 days, SN1:100 % NPK + hydrogel, SN2:75 % NPK + hydrogel, SN3: 50 % NPK + hydrogel, and SN4:100% NPK without hydrogel (control).

Table 6. Influence of irrigation frequencies, soil applications, and their interactions on cowpea plant content of NPK and uptake in the two seasons.

		N %		P %		K %		Uptake N (Kg/fed)		Uptake P (Kg/fed)		Uptake K (Kg/fed)	
		S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
Irrigation frequencies (IF)													
2 days		4.01	3.61	0.40	0.48	1.42	1.41	218.37	182.33	21.47	24.37	77.07	70.98
3 days		4.32	3.87	0.43	0.52	1.47	1.47	249.22	208.03	24.76	28.06	84.82	78.67
4 days		3.51	3.10	0.33	0.42	1.36	1.29	166.88	140.48	15.98	19.17	64.79	58.26
LSD 0.05		0.41	0.34	0.07	0.04	N.S	0.09	21.04	14.22	2.96	2.44	11.01	6.00
Soil applications (SN)													
SN1		4.15	3.72	0.40	0.50	1.45	1.46	233.74	193.02	22.38	25.77	81.40	75.05
SN2		4.39	3.93	0.43	0.51	1.45	1.45	250.59	210.07	24.81	27.40	82.87	77.34
SN3		3.63	3.31	0.35	0.46	1.38	1.31	186.69	158.17	18.37	22.03	71.06	62.94
Control		3.62	3.14	0.36	0.43	1.39	1.33	174.94	146.53	17.39	20.25	66.91	61.89
LSD 0.05		0.48	0.44	0.10	0.08	N.S	0.12	23.32	25.85	3.62	4.56	8.05	6.87
Interaction													
IF1	SN1	4.20	3.80	0.41	0.50	1.45	1.47	249.18	205.50	24.46	26.81	85.93	79.20
	SN2	4.37	3.97	0.42	0.50	1.46	1.49	261.63	214.94	25.01	27.06	87.40	80.66
	SN3	3.79	3.39	0.36	0.46	1.36	1.29	195.52	161.14	18.81	22.12	70.25	61.79
	Con	3.68	3.28	0.39	0.48	1.42	1.38	167.15	147.73	17.59	21.47	64.69	62.27
IF2	SN1	4.72	4.18	0.43	0.54	1.49	1.49	276.20	231.67	25.21	29.75	87.73	82.75
	SN2	4.80	4.30	0.49	0.55	1.52	1.50	292.57	249.64	29.87	32.14	92.63	86.99
	SN3	3.81	3.41	0.40	0.48	1.45	1.42	215.51	170.62	22.42	24.13	81.82	71.64
	Con	3.97	3.57	0.40	0.52	1.44	1.45	212.60	180.20	21.52	26.21	77.10	73.30
IF3	SN1	3.53	3.16	0.35	0.46	1.41	1.41	175.83	141.88	17.45	20.74	70.53	63.19
	SN2	3.98	3.51	0.39	0.49	1.38	1.37	197.57	165.63	19.55	22.99	68.56	64.37
	SN3	3.28	3.13	0.30	0.44	1.34	1.22	149.04	142.74	13.86	19.87	61.10	55.40
	Con	3.23	2.59	0.29	0.30	1.31	1.16	145.08	111.65	13.06	13.07	58.95	50.09
LSD 0.05		1.03	1.20	0.70	0.10	N.S	0.13	N.S	57.71	4.06	5.12	13.58	7.85

IF1: watering each 2 days, IF2: watering each 3 days, IF3: watering each 4 days. SN1:100 % NPK + hydrogel, SN2:75 % NPK + hydrogel, SN3: 50 % NPK + hydrogel, and SN4:100% NPK without hydrogel (control).

Table 7. Influence of irrigation frequencies, soil applications, and their interactions on land equivalent ratio (LER) in the two seasons.

IF x SN		RYm	RYc	LER	RYm	RYc	LER
		S1			S2		
IF1	SN1	0.95	0.58	1.53	0.95	0.54	1.49
	SN2	0.88	0.58	1.46	0.88	0.54	1.42
	SN3	0.77	0.50	1.27	0.80	0.48	1.28
	SN4	0.83	0.45	1.28	0.85	0.45	1.30
IF2	SN1	0.94	0.57	1.51	0.93	0.56	1.49
	SN2	0.86	0.59	1.45	0.89	0.58	1.47
	SN3	0.77	0.55	1.32	0.77	0.50	1.27
	SN4	0.75	0.52	1.27	0.76	0.51	1.27
IF3	SN1	0.90	0.48	1.38	0.92	0.45	1.37
	SN2	0.78	0.48	1.26	0.80	0.48	1.27
	SN3	0.71	0.44	1.15	0.71	0.46	1.17
	SN4	0.64	0.43	1.07	0.66	0.43	1.09
Sole maize		1.00	-	1.00	1.00	-	1.00

IF1: watering each 2 days, IF2: watering each 3 days, IF3: watering each 4 days. SN1:100 % NPK + hydrogel, SN2:75 % NPK + hydrogel, SN3: 50 % NPK + hydrogel, and SN4:100% NPK without hydrogel (control).

Table 8. Effect of irrigation frequencies, soil applications and their interaction on economic return in the two seasons.

IF x SN		Gross return (L.E/fed)		Total cost (L.E/fed)		Net return (L.E/fed)	
		S1	S2	S1	S2	S1	S2
IF1	SN1	16398	17500	11835	12837	4563	4663
	SN2	15478	16614	11394	12377	4084	4237
	SN3	13536	15008	10953	11916	2584	3092
	SN4	14164	15689	11435	12337	2729	3352
IF2	SN1	16473	17532	11460	12462	5013	5070
	SN2	15344	16878	11019	12002	4326	4877
	SN3	13735	14681	10578	11541	3158	3140
	SN4	13359	14553	11060	11962	2299	2591
IF3	SN1	15296	16788	11260	12262	4036	4526
	SN2	13548	14904	10819	11802	2729	3102
	SN3	12407	13538	10378	11341	2029	2197
	SN4	11470	12465	10860	11762	610	703
Sole maize		14485	15906	11205	12077	3280	3829

IF1:watering each 2 days, IF2: watering each 3 days, IF3: watering each 4 days, SN1:100 % NPK + hydrogel, SN2:75 % NPK + hydrogel, SN3: 50 % NPK + hydrogel, and SN4:100% NPK without hydrogel (control).

Conclusion

Based on the obtained data, it can be concluded that amending sandy soil with hydrogel could reduce the irrigation frequency from irrigation once every 2 to 3 days, without significant yield and economic return reduction. Furthermore, incorporation of inorganic 100 % NPK with hydrogel has demonstrated the ability to produce greater yields, nutrient content and uptake of grain maize, land equivalent ratio (LER), and net return /fed. While embedding 75% of NPK with hydrogel gave a higher forage yield of cowpea, nutrient content, and NPK-uptake.

References

Abdallah, A. M. (2019). The effect of hydrogel particle size on water retention properties and availability under water stress. Intl. Soil and Water Conservation Res., 7: 275-285.

Abo-Marzoka, E.A., El-Mantawy, Rania. F.Y., Soltan, Iman. M. (2016). Effect of irrigation intervals and foliar spray with salicylic and ascorbic acids on maize. J. Agric. Res. Kafr El-Sheikh Univ., 42(4): 506-518.

Agaba, H., Orikiriza, L. J., Obua, J., Kabasa, J. D., Worbes, M., and Hüttermann, A. (2011). Hydrogel amendment to sandy soil reduces irrigation frequency and improves the biomass of Agrostis stolonifera. Agric. Sci., 2 (04): 544-550.

Albuquerque, A. C., Rodrigues, J. S., de Freitas, A. S., Machado, G. T., and Botaro, V. R. (2022). Renewable source hydrogel as a substrate of controlled release of NPK fertilizers for sustainable management of eucalyptus urograndis: field study. ACS Agric. Sci. & Tech., 2(6): 1251-1260.

Ali, O. M. and M.S.M. Abdel-Aal (2021). Importance of some soil amendments on improving growth, productivity and quality of soybean grown under different irrigation intervals. Egypt. J. of Agron., 43(1): 13-27.

Ali, O., and Abdelaal, M. (2020). Effect of irrigation intervals on growth, productivity and quality of some yellow maize genotypes. Egyptian Journal of Agronomy, 42(2): 105-122.

A.O.A.C. (1990). Official Tentative Methods of Analysis of Association of Official Analytical Chemists. Washington. D.C., USA,15 Edth.

Bala, A. G., Hassan, M. R., Tanko, R. J., Hassan, A. H., Bature, M.S., Mohammed, A., Alhabib, I. K., and Salihu, A.I. (2021). Effects of irrigation schedule and phosphorus fertilizer rates on forage yield of two cowpea varieties in Nigeria. Nigerian J. of Animal Sci. and Technology (NJAST), 4(1):10-18. Retrieved from http://njast.com.ng/index.php/home/article/view/128.

Bulletin of Statistical Cost Production and Net Return (2021 and 2022). Summer Field Crops and Vegetables and Fruit, Agric. Statistics and Econ. Sector, Minist. Egypt. Agric. and Land Reclamation, Part (2).

Chapman, H.D., and Pratt, P.F. (1961). Methods of analysis for soils, plants and water. Division of Agric Sci, Berkeley Univ., California, USA, pp 150–152.

Dhakal, Y., Meena, R.S., and Kumar, S. (2016). Effect of INM on nodulation, yield, quality and available nutrient status in soil after harvest of green gram. Legum Res., 39 (4):590–594.

DWR (2013). Directorate of Wheat Research Progress Report 2013, Vol. II.

Ehsas, N., Iqbal, M. A., and Ahmadi, S. M. (2018). Effect of Irrigation Intervals on forage production and quality of different alfalfa varieties under semi-arid conditions. Intl. J. of Environ., Agric. and Biotech., 3(6):2043-2050.

El Shahawy, H. A., El-Sherbieny, A.E., Sheha, A.A. and Habashy, N.R. (2020). Impact of irrigation water regimes and anti-transpirations with hydro-gel on nutritional status of peanut grown in sandy soil. Zagazig J. of Agric. Res., 47(4), 963-974.

El-Mehy, A. A., Abd Allah, A. M., Mohamed, T. S., and Kasem, E. E. (2020). Intercropping of some faba bean cultivars with sugar beet using different irrigation intervals under sprinkler system in sandy soils. Journal of Plant Production, 11(12), 1215-1225.

El-Mehy, A.A., Shehata, M.A., Mohamed A.S., Saleh, S.A., and Suliman A.A. (2023). Relay intercropping of maize with common dry beans to rationalize nitrogen fertilizer. Front. Sustain. Food Syst. 7:1052392. doi: 10.3389/fsufs.2023.1052392.

El-Sobky, E.E.A., and Desoky, E.M. (2017). Influence of irrigation interval, bio and mineral fertilization and their interactions on some physiological, anatomical features and productivity of maize. Zagazig J. Agric. Res. 44 (1): 23-40.

El-Syed, N. M., M. Helmy, A., Fouda, S. E., M. Nabil, M., Abdullah, T. A., K. Alhag, S., and Elrys, A. S. (2023). Biochar with Organic and Inorganic Fertilizers Improves Defenses, Nitrogen Use Efficiency, and Yield of Maize Plants Subjected to Water Deficit in an Alkaline Soil. Sustainability, 15 (16): 12223.

Farouk, S., Arafa, Sally A., Nassar, and Rania, M.A. (2018). Improving drought tolerance in corn (*Zea mays* L.) by foliar application with salicylic acid. Int. J. Environ. 7(3), 104-123.

Fei et al. (2019). Phosphorous retention and release by sludge-derived Hydrochar for potential use as a soil amendment. J. of Environm. Quality, 48 (2):502-509.

Frei, E., K. Payer and E. Schutz, (1964). Determination of phosphorus by ascorbic acid method. Schw. Landwirtsch-Forschung. Heft., 3: 318-328.

Freed R.D. (1991). MSTATC Microcomputer Statistical Program. Michigan State University, East Lansing, Michigan, USA.

Geeth, R. H. M. (2019). Effect of planting dates and drip irrigation rates on growth, yield and its components of cowpea (*vigna unguiculata* l. Walp) plants under sandy soil conditions. Menoufia Journal of Plant Production, 4(2), 103-117.

Ghanbari, A., Dahmardeh, M., Siahsar, B. A., and Ramroudi, M. (2010). Effect of maize (Zea mays L.)-cowpea (Vigna unguiculata L.) intercropping on light distribution, soil temperature and soil moisture in arid environment.

Haque, M. P. H., Hossain, M. A., Biswas, S. K., & Chowdhury, S. K. H. (2020). Impact of Irrigation at Different Growing Stages on Yield, Crop Water Productivity, and Profitability of Cowpea (*Vigna unguiculata* L.) in Bangladesh. J. of Agric. Sci. & Engineering Innovation (JASEI), 1(1): 15-22. Retrieved from https://rsepress.org/index.php/jasei/article/view/14

He M, Dijkstra FA (2014) Drought effect on plant nitrogen and phosphorus: a meta-analysis. New Phytol., 204(4):924–931.

Hiama, P. D., Ewusi-Mensah, N., & Logah, V. (2019). Nutrient uptake and biological nitrogen fixation in cowpea under biochar-phosphorus interaction. J. of Animal and Plant Sci., 29: 1654-1663.

Huang, R., Birch, C. J., & George, D. L. (2006). Water use efficiency in maize production-the challenge and improvement strategies. In Proceeding of 6th Triennial Conference, Maize Association of Australia.

Irmadamayanti, A., Wahyuni, A. N., and Padang, I. S. (2021). Assessment of irrigation water interval on maize in dry land in central Sulawesi. In IOP Conference Series: Earth and Environmental Science (Vol. 762, No. 1, p. 012055). IOP Publishing.

Kalhapure, A., Kumar, R., Singh, V. P., & Pandey, D. S. (2016). Hydrogels: a boon for increasing agricultural productivity in water-stressed environment. Current Sci., 1773-1779.

Kumar, R., Nadukeri, S., Kolakar, S. S., Hanumanthappa, M., Shivaprasad, M., & Dhananjaya, B. N. (2018). Effect of hydrogel on growth, fresh yield and essential oil content of ginger (Zingiberofficinale Rosc.). J. of Pharmacognosy and Phytochemistry, 7(3S), 482-485.

Layek, J., Das, A., Mitran, T., Nath, C., Meena, R. S., Yadav, G. S., ... & Lal, R. (2018). Cereal+ legume intercropping: An option for improving productivity and sustaining soil health. Legumes for soil health and sustainable management, 347-386.

Liu, X., Li, Y., Meng, Y., Lu, J., Cheng, Y., Tao, Y., & Wang, H. (2021). Pulping black liquor-based polymer hydrogel as water retention material and slow-release fertilizer. Industrial Crops and Products, 165, 113445.

Lima Filho, J. M. P. (2000). Physiological responses of maize and cowpea to intercropping. Pesquisa Agropecuária Brasileira, 35, 915-921.

Lotfi, R., Kalaji, H. M., Valizadeh, G. R., Khalilvand Behrozyar, E., Hemati, A., Gharavi-Kochebagh, P., & Ghassemi, A. (2018). Effects of humic acid on photosynthetic efficiency of rapeseed plants growing under different watering conditions. Photosynthetica, 56, 962-970.

Marashi, S. K., & Mombani, P. (2020). Effect of super absorbent polymer on quantitative and qualitative traits of cowpea (Vigna unguiculata L.) in low irrigation management conditions. Iranian J. Pulses Res., 11(1), 124-133.

Montesano, F. F., Parente, A., Santamaria, P., Sannino, A., & Serio, F. (2015). Biodegradable superabsorbent hydrogel increaseswater retention properties of growing media and plant growth. Agriculture and Agricultural Science Procedia, 4, 451-458.

Nirmala, A., & Guvvali, T. (2019). Hydrogel/ superabsorbent polymer for water and nutrient management in horticultural crops. IJCS, 7(5), 787-795.

Öktem, A. (2006). Effect of different irrigation intervals to drip irrigated dent corn (Zea mays L. indentata) water-yield relationship. Pakistan Journal of Biological Sciences, 9(8), 1476-1481.

Ovalesha MA, Yadav B, Rai PK (2017). Effects of polymer seed coating and seed treatment on plant growth, seed yield and quality of Cowpea (*Vigna unguiculata*). J.of Pharmacognosy and Phytochemistry, 6 (4):106-109.

Saini A. K. and S. H. Malve (2023). Impact of Hydrogel on Agriculture – A review. Eco. Env. & Cons. 29:36-47.

Shankarappa, S. K., Muniyandi, S. J., Chandrashekar, A. B., Singh, A. K., Nagabhushanaradhya, P., Shivashankar, B., ... & Elansary, H. O. (2020). Standarizing the hydrogel application rates and foliar nutrition for enhancing yield of lentil (Lens culinaris). Processes, 8(4), 420.

Solanki, R.; Bisen, B. P. and Pandey, S. K. (2021). Effect of super absorbent polymer and irrigation scheduling on growth attributes in acid lime. IJCS, 9(1): 360-363.

Wei, Y., and Durian, D. J. (2014). Rainwater transport and storage in a model sandy soil with hydrogel particle additives. The European Physical Journal E, 37(97): 1-11. https://doi.org/10.1140/epje/i2014-14097-x.

Willey, R.W. (1979): Intercropping-Its importance and research needs part.1- competition and yield advantage. Field Crop Res., 32:1-10.

Yasin, M.A.T. (2016) Response of two yellow maize hybrids to irrigation intervals and nitrogen fertilizer levels. J. plant produc., Mansoura Univ., Egypt, 7(12): 1465 -1472.

Yaseen, R., Hegab, R., Kenawey, M., & Eissa, D. (2020). Effect of super absorbent polymer and bio fertilization on Maize productivity and soil fertility under drought stress conditions. Egypt. J. of Soil Sci., 60(4), 377-395.

Zhang, G., Shen, D., Ming, B., Xie, R., Jin, X., Liu, C., ... & Li, S. (2019). Using irrigation intervals to optimize water-use efficiency and maize yield in Xinjiang, northwest China. The Crop J., 7(3): 322-334.

تأثير إضافة بعض محسنات التربة على كفاءة التسميد وإنتاجية الذرة الشامية ولوبيا العلف المحملين تحت ظروف الإجهاد المائي بالأراضي الرملية

أحمد محمد عبدالله[1]، و رحاب حلمى حجاب[2]، و أميرة عطية الميهى[1]

[1] قسم بحوث التكثيف المحصولى- معهد بحوث المحاصيل الحقلية- مركزالبحوث الزراعية- مصر
[2] قسم خصوبة، ميكروبيولوجيا الأراضى، مركز بحوث الصحراء- المطرية- القاهرة- مصر

تم إجراء تجربة حقلية بمحطة البحوث الزراعية بالإسماعيلية بمصر- خلال الموسم الصيفي 2021 و 2022، لدراسة تأثير تكرار الري كل (2، 3 و 4 أيام، اختصارها IF1, IF2 and IF3) و معاملات التربة (إضافة الهيدروجيل مع NPK غير العضوي) وهى [SN1 (100% NPK + هيدروجيل)، SN2 (75% NPK + هيدروجيل)، و SN3 (50% NPK + هيدروجيل) بالإضافة إلى الكنترول SN4 (100% NPK بدون هيدروجيل)] وتفاعلهما على الإنتاجية ، محتوى النبات والممتص من NPK ،نسبة المكافئ الأرضى (LER) والعائد الاقتصادي للذرة ولوبيا العلف المحملة. سُجلت أعلى القيم لمحصول حبوب الذرة ومكوناته بالإضافة إلى محتوى حبوب الذرة والممتص من NPK بالري مرة كل يومين (IF1) مع SN1، يليه الري مرة واحدة كل 3 أيام (IF2) ومعاملة التربة SN1. لم يظهر التفاعل بين IF2 x SN1 والمعاملة IF1 x SN1 فرقًا معنوية للصفات السابقة. أدت معاملة الري (IF1 وIF2) مع تطبيق 75% NPK مع الهيدروجيل (SN2) إلى تحسين عدد الفروع لكل نبات والمحصول الغض من لوبيا العلف، وكذلك محتوى النبات من NPK وامتصاص NPK. بينما سجلت أقل القيم لجميع الصفات المدروسة لكلا المحصولين مع أقل تكرار للري (IF3) بالإضافة إلى الكنترول (التربة غير المعاملة بالهيدروجيل (SN4)). كذلك حققت التفاعل بين IF1x SN1 أعلى القييم للمكافئ الأراضي (1.51)، وكانت على قدم المساواة مع المعاملة IF2xSN1 (1.50). بينما تحقق أعلى صافي دخل مع المعاملة IF2xSN1 مقارنة بالمعاملات الأخرى. الخلاصة، يمكننا تطبيق الرى مرة واحدة كل 3 أيام ومعاملة التربة بـ (100% NPK + الهيدروجيل) لتقليل تكرارالرى من 2 إلى 3 أيام وزيادة الإنتاجية ومحتوى النبات من العناصر، وكذلك المكافئ الأرضى LER وصافي الدخل للذرة ولوبيا العلف.