The Effect of Extending Irrigation Intervals on Growth and Yield Attributes and Harvest Indices of Groundnut (Arachis hypogaea L.) in Clay Soil

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Abstract

The main question that drived and guided this study was how to grow groundnut as food crop with conservation in freshwater resource in arid climate. As a result, this field study was carried out for two years (2021/2022 and 2022/2023) to investigate the effects of constant input of irrigation water (93mm), applied at intervals of 7, 14, 21, and 28 days, on the growth and yield of MH383 groundnut cultivar. The effects were viewed regarding growth and yield and water use efficiency (m3 of water / Kg dry matter) of groundnut MH3 cultivar to assess the optimum policy to conserve irrigation water. The results indicated that extending irrigation interval to reduce consumption of irrigation water resulted in a clear reduction of vegetative and reproductive growth attributes (plant height, leaf area, dry matter production, number of pegs per plant, number and dry weight of pods per plant, 100-seed weight and harvest index). These reductions were naturally reflected in reduced hay and pod yields. The number and dry weight of pods per plant were the yield components most affected by decreased watering. Frequent watering resulted in improved pod and hay yield. Such reduction is manifested in the number and dry weight of pods per plant. The results of the experiment showed that leaf area indices of plants stressed during the vegetative phase were higher during the mid and late season (reproductive phase). For irrigated groundnut, it is possible to increase field water use efficiency, dry matter production, and crop yield, by imposing a transient deficit in soil moisture using 14-day irrigation intervals or even 21-day intervals of severe water shortage without significant loss on crop productivity.

Keywords: Conserve Irrigation, Groundnut, Prolonging Irrigation Intervals

Introduction

Irrigation water resources of Sudan are limited with a fixed share of Nile water, climate changes, increase in population, and expansion of irrigated areas. Therefore, the main question that drives and guide this study was: how to conserve irrigation water in arid climate zone in general, and in the Sudan with its almost exploited water in particular, to grow field food crops such as groundnut crop. This requires adopting field management and cultural practices to reduce consumption of irrigation water. Hence, the adopted rationale is to employ deficit irrigation by prolonging the irrigation interval of field crops. The main field crops cultivated in irrigated schemes in Sudan are cotton, sorghum, groundnut, and wheat. Groundnut crop is sown under irrigation in Sudan's central clay plains in Gezira, New Halfa, El Rahad, and El Suki irrigated schemes during summer (May–June July).

Groundnut is a significant source of oil (51%), protein (28%), and minerals (2.5%). Groundnut (Arachis hypogaea L.) is an annual legume and oilseed crop and is a member of the subfamily Papilionaceous of the family Leguminosae. According to Mahendra et al. (2021), ground nut seed (kernel) consists of 44-50% oil, 44-56% fat, 26% protein, and 10-20% carbohydrate. The important countries in the order of groundnut production are India, China, the U.S.A., Indonesia, Senegal, Nigeria, Myanmar, Sudan, and Argentina (FAO 2016, Singh, et al 2013). While the area and production of groundnuts have been increasing in the world, however, the total productivity remained almost constant (FAOSTAT, 2016, FAO, 2016,). This is because; rainfall plays an important role in groundnut production in many countries (Singh et al, 2013). Low rainfall and prolonged dry spells during the crop growth period. Sudan accounts for about 50 percent of global production, while other developing countries in the semi-arid tropics contribute 60 percent. The average in-shell yield is 900 kg/ha (FAO, 2000). High and stable groundnut productivity is an essential element in the improvement of efficiency of farming systems in the semi-arid lands of South–East state of Sudan. Groundnut is an important component of inter-cropping systems, and the haulm provides fodder for live stalks. The crop is primarily rain-fed, and soil moisture is a primary constraint on yield. Even though Groundnut is fairly drought-tolerant, production fluctuates considerably because of rainfall variability. The productivity under dry land conditions is largely determined by the availability of rainfall received during the stage of gynophore formation and initial pod development (Hussainy and Arivukodi, 2020). Water use by groundnuts in different cropping seasons in different parts of the world varies between 250 mm under rain-fed conditions (Singh et al., 2013) to 831 mm under irrigated conditions (irrigation at intervals of seven to ten days during summer months). The total water use of a groundnut crop is reported to be affected by scheduling irrigations based on requirements at the various growth stages (Singh et al, 2013) and is lowest from germination to flower formation and reaches maximum during pod formation. Soil moisture stress at the critical stage of gynophore formation may lead to severe yield reductions, resulting in heavy crop loss (Hussainy and Arivukodi, 2020).

Thiyagarajan et al (2009) reported that for India there is a high level of fluctuation in the productivity of groundnut depending on the rainfall as 70 percent of the area is under semi-arid tropics characterized by low and erratic rainfall. They stated that not only the yield but also other yield attributes, growth, and development are affected by soil moisture deficit or water stress. They confirm that the maintenance of optimum soil moisture at critical growth stages is the key factor for achieving higher yields. The knowledge of physiological characteristics like photosynthesis, stomatal conductance, leaf water potential, and water use efficiencies would certainly help make irrigation scheduling of groundnut and decision support systems that aim at higher productivity. To develop a water stress response function in groundnut, more research works need to be done to improve the performance under varying degrees of stress at various physiological stages of crop growth. This calls for developing information on drought resistance characteristics of groundnuts to develop appropriate genetic enhancement strategies and field management practices for water-limited environments.

A study was conducted in the Sudan Savannah Zone of Nigeria on the effect of groundnut variety, intra-row spacing, and irrigation interval on various growth parameters and yield attributes of groundnut crops. Treatments consisted of three varieties of groundnut (SAMNUT 24, SAMNUT 25, and SAMNUT 26), three intra-row spacing (15, 20, and 25cm), and three irrigation intervals (3, 6, and 9 days). The treatments were factorized and laid out in a randomized complete block design (RCBD) replicated three times. Results from the study revealed that ground nut variety had a significant ($P \leq 0.05$) effect on growth and yield parameters at the two locations. The study indicated that a 6-day irrigation interval on kernel weight per plant recorded a significant effect at the two locations studied (Ibrahim, et al, 2021).

Syed Abul Hassan and Vaidyanathan (2019) conducted a field experiment at the Research Station, Tamil Nadu -India during the kharif season of 2017 and 2018 to study the influence of intercropping under different levels of irrigation on the performance and nutrient dynamics of groundnut. Application of water at (IW/CPE) ratio of 0.75 comprising 7 irrigations (enhanced the productivity in terms of equivalent intercrop yield as well as sole crop yield.

Yadav et al (2013) conducted a field experiment in split plot design at B.A. College of agriculture; AAU, Anand during the kharif season of 2009. They tested two dates of sowings of two groundnut cultivars with two irrigation levels. The results of their field experiments revealed that pod and haulm yields as well as test weight and shelling percentage did not differ due to the date of sowing. Similarly, growth and yield attributing parameters like the weight of mature and immature pods per plant, number of mature and immature pods per plant, plant height, and number of branches per plant also do not differ due to the date of sowing. The differences in pod yield shelling percentage and mature pod weight per plant were found significant due to varieties. The irrigation treatment exerted no significant effect. It might be due to well-distributed rainfall received during the crop season.

In the Gezira Scheme in Sudan, irrigation practices for crops like sorghum and groundnut have been studied by Ahmed et al (2002) to improve water-use efficiency. The research has identified water waste in both traditional attended daytime water applications and unattended continuous watering methods. For groundnuts, specifically, the study suggests that there is a need for more frequent land leveling to minimize standing water and better farm management to reduce water waste. Regarding the irrigation interval for groundnuts, it’s generally recommended to apply irrigation at intervals of 7-10 days during flowering, 10-15 days during pegging, and 15-20 days during pod development (Singh et al 2013). However, these intervals might be adjusted based on the actual soil moisture deficit, which can be determined using methods like neutron scattering as mentioned in the studies. Ahmed et al (2002) concluded that for the Gezira Scheme, implementing measures such as better attended irrigation and improved farm management can significantly reduce unproductive water loss and enhance water-use efficiency. It’s important to tailor irrigation practices to the specific conditions of the scheme and the moisture requirements of the groundnut crop to achieve optimal results.

Irrigation is a crucial aspect of groundnut cultivation, and it's important to manage it effectively to ensure a good yield. From the literature review, (Ahmed et al 2002, Mungla and Chooneea,2016, Mahendra et al, 2021), the key points for groundnut irrigation are Water Requirements: Groundnuts require an average of 420 mm to 820 mm of water during their entire growth period(Ahmed et al 2002, Mungla and Chooneea 2016, Mahendra et al, 2021). However, Singh et al (2013) states that groundnut crop needs ten irrigations with 1070 m3 per hectare per irrigation and at 14-day intervals.Critical Stages for Irrigation: At Sowing: soil should be moist. If dry, irrigate 2-3 days before sowing or immediately after sowing. Flowering: Most critical stage; irrigate every 7-10 days to avoid poor pod development.Pegging: When plants develop pegs; irrigate every 10-15 days.Pod and Seed Development: Irrigate every 15-20 days. For irrigation intervals irrigate deeply and infrequently to encourage deep rooting and drought tolerance. Water early in the morning or late in the evening to minimize evaporation losses. Monitor soil moisture content regularly and irrigate as needed.In agreement with Gezira irrigation practices, Ishag et al. (1985) confirmed that the highest yield is obtained with a 7-day interval, and it is of no significant difference to 14 days yield (difference of only 7.8%). The average yields (1 400 kg/ha) of the irrigated summer season crop are almost double those obtained in the rainy season. One of the pioneer studies on water stress response function in groundnuts was conducted by Ibrahim et al,(2021) who investigated the effects of extending watering intervals on Groundnut (Arachis hypogaea L.) growth and yield attributes and harvest indices. The main outcome of his study confirmed the recommendation of Ishag et al. (1985) which is to employ a short watering interval of 7 days. The key factor affecting growth and yield is moisture availability during the cropping season. Groundnut was reported to be a drought-tolerant crop due to its well-established root system in the soil top 60 cm (Singh et al., 2013). Ahmed et al (2002) observed that groundnut causes a significant change in moisture in the top 30 cm of the soil, with a decrease in moisture as depth increases. The onset of moisture stress can be observed when pods are formed in the top 8 cm of the soil, indicating the need for frequent watering of the top surface layers. ICRISAT. 2012). Banavath et al (2018), and Sui et al (2015) attributed groundnut drought tolerance ability to its indeterminate characteristics that offer greater yield stability with occurrences of short drought stresses during vegetative or early reproductive phases. Reddy et al (2003), and Singh et al (2013) pointed out that water stress during pod development decreases the germination of seeds in the following sowing season. Ishag et al. (1985) reported a sharp increase and longer persistence of leaf area index with frequent watering, resulting in increased production of branching. While, for stressed plants, there is an earlier decrease in surface area index due to the fewer branches resulting in fewer leaves per plant and a reduction of assimilation rate before and after pegging. Mahendra et al (2021) made a field experiment on the effect of two irrigation levels (0.8 and 0.6 Potential evaporation (PE)), and two intervals (alternate and 3 days) and three cultivars on groundnut (Arachis hypogaea L.) under drip system in split plot design and replicated thrice was conducted at Instructional Farm, S.K. Rajasthan Agricultural University, Bikaner during Kharif 2019. The obtained results revealed that 0.80 PE gave higher dry matter accumulation, pods/plant (44.13), kernels/pod (2.38), pod yield (3117 kg/ha), haulm yield (4081 kg/ha), biological yield (7199 kg/ha), test weight (446.58 g) and oil yield (978.32 kg/ha) followed by 0.60 PE. Alternate day irrigation intervals gave higher dry matter accumulation, crop growth rate, pods/plant (43.55), kernels/pod (2.36), pod yield (2993kg/ha), haulm yield (3986 kg/ha), biological yield (6980 kg/ha), test weight (443.22g) compared to 3 days irrigation intervals. There are marked differences between cultivars in terms of all yield attributes. Therefore, there is a need for strategies that maximize the efficiency of use of the available limited amounts of water. Therefore, a study is required to confirm the recommendations of Mahendra et al (2021) and Ibrahim et al (2021) regarding adopting short irrigation intervals. Moreover, there is a need to examine the effects on crop growth, yield attributes, harvest indices, and water use efficiency (WUE) due to different irrigation scheduling practices including extended irrigation intervals, water shortage, and stress at different growth stages to take the advantage of the reported crop drought tolerance and deep root system to conserve water at late growth stages. Consequently, this study was conducted with four moisture-deficit regimes during two seasons by prolonging irrigation interval to 7, 14, 21, and 28 days and filling the crop root zone to field capacity during the crop establishment phase (initial stages) by adding only 92 mm of irrigation water per each irrigation and let the crop roots extract his additional water need from the deeper layers in clay soil.

Materials and Methods

Study Location

The experiment was conducted in clay soil, with 63.6–64.2% clay at the Demonstration Farm of the College of Agricultural Studies, Shambat, Sudan Khartoum North, Sudan (Latitude 15° 40' N and longitude 32° 32' E) during 2021/2022 and 2022/2023 seasons. The area of the experiment is classified as a semi-arid region, fading to an arid area. The physical characteristics of the study area are depicted in Table 1. The soil of the study area is deep, and heavy soil (Vertisols).

Table 1:: The physical characteristics of the soil of the experimental site

Diversity Taxa_S	**Biodiversity Index Values**			**Diversity**	**Biodiversity Index Values**		
	15	Taxa_S	15		0-15 cm	15-30 cm	30-60 cm
Individuals	664	Individuals	664	Field capacity (%)	36.6	35.7	34.7
Dominance	0.1374	Dominance	0.1374	Permanent wilting point (%)	17.4	14.4	13.9
Shannon_H’	2.271	Shannon_H’	2.271	Bulk density (g/cm)	1.25	1.35	1.35
Evenness_e^H/S	0.6457	Evenness_e^H/S	0.6457	pH	7.8	7.8	7.7

Data collection Treatments and Experimental Arrangements

Data collection determination was based on the procedures given by (El Amin, et al ,1983, Gomez, . and Gomez, 1984, and Ahmed ,1993, as detailed in next sections of this paper. The experiment plots were 10x 8 m. The four borders of each plot were raised to about 60 cm above the soil surface. The experimental land was prepared by disc plowing, harrowing, leveling, and ridging. The crop was sown at a spacing of 15 cm apart on ridges of 80 cm spacing on the 2nd of July 2021 and 2022. Three plants were sown per hole and then thinned into two plants. After 28 days, furrows were re-ridged (Green ridging) to earthen the soil around plant pegs, facilitate water advance in furrows and for weeding. After that manual weeding was carried out three times during each growing season. Adopted crop cultural practices for cultivating the experimental MH383 Groundnut variety are typical to those recommended by Agricultural Research Corporation (ARC), Wad Madani The field experiment was arranged in a randomized complete block design, with three replications,

a. *Establishment Period:* Four irrigations (372mm) were equally applied at 7-day intervals to all experimental units for the establishment of the plants until they were 28 days old. This was made to establish the crop and avoid a severe reduction in crop yield (Hussainy and Arivukodi, 2020).

b. *Experimental Period:* The water quantities for each treatment consisted of four levels achieved by applying constant water amount (93 mm) to fill the root zone moisture capacity but given at the four irrigation intervals (Ahmed et al, 2002) 1860.1209, 1023, 837 in season 2021/2022, and 1767, 1116, 930 and 744 mm in season 2022/2023). These moisture-deficit regimes were applied by prolonging irrigation interval to 7, 14, 21, and 28 days and filling the crop root zone to field capacity by adding a constant depth of 93 mm of irrigation water per irrigation (Ahmed et al ,200). At 7,14-,21-, and 28-day intervals 1488, 837, 651, and 465 mm were applied in 20,13,11, and 9 irrigation numbers for season 2021/2022respectively during the experimental period (Table 2 A). Likewise, in season 2022/2023). and at 7,14-,21-, and 28-day intervals 1395,744,558, and 372mm were applied in 19,12,10, and 8 irrigation numbers respectively during the experimental period (Table 2 B). The watering flow rate was controlled by a Vane flow meter in the supply ditch and 2-inch Parshall flumes per furrow.

Table 2: Number of Irrigation, Amount of Water Per Irrigation, and Total Water Applied for Each Treatment During The 2021/2022 And 2022/2023 Seasons.

A- Season 2021/2022

Diversity			**Biodiversity Index Values**			**Diversity**	
Taxa_S	15	Taxa_S	Amount per irrigation	No. of Irrigation during the experiment	Water Applied During the experiment	Total No of Irrigation	Total Seasonal Water Applied
Individuals	664	Individuals	(mm)	No.	mm	No.	mm
Dominance	0.1374	Dominance	93	16	1488	20	(372+1488) =1860
Shannon_H'	2.271	Shannon_H'	93	9	837	13	(372+837) =1209
Evenness_e^H/S	0.6457	Evenness_e^H/S	93	7	651	11	(372+651) =1023
Simpson_1-D	0.8626	Simpson_1-D	93	5	465	9	(372+465) =837
Diversity	Biodiversity Index Values	Diversity					

B- Season 2022/2023

Per-experimental period		**Experimental period**				**Total Irrigation**	
Activity	Amount/ Irrigation every 7 days	Experimental Treatment	Amount per irrigation	No. of Irrigation during the experiment	Water Applied During the experiment	Total No of Irrigation	Total Seasonal Water Applied
7-day Interval	(mm)	Irrigation Interval (days)	(mm)	No.	mm	No.	mm
1st irrigation	93	7	93	15	1395	19	(372+1395) =1767
2nd irrigation	93	14	93	8	744	12	(372+744) =1116
3rd irrigation	93	21	93	6	558	10	(372+558) =930
4th irrigation	93	28	93	4	372	8	(372+372) =744
Total amount in 4 irrigations (30 days)	372						

Soil Moisture Determination: Soil moisture was determined before each irrigation by oven-dry method for the depths 20, 40, and 60 cm on a weight basis, and then was converted to volumetric water content by multiplication with the soil bulk density. The soil bulk density was determined by the procedure used by Arshad et al (2014) and higher values were measured as: 1.6, 1.66, and 1.67 for 20, 40, and 60 cm depth respectively. Table 3 shows the soil water content.

c. *Plant Growth and Yield Attributes:* In each plot area (1×8 m) ten ridges were mechanically constructed. The third and fourth ridges were used for taking destructive samples, whereas the fifth and sixth ridges were assigned for sampling the yield components, and ridges number seven and eight were harvested to determine the final yield. Three plants were taken per sample. The crop growth attributes measured from each sample are:

1. Main stem plant height (cm)
2. Number of pods per plant
3. Dry weight of pods per plant (gm/plant): Sun drying
4. Plan dry matter production (g/plant)
5. Leaf area index: determined by total leaf area (leaf length by maximum width) to total ground area

d. For determining yield components, samples of four plants were taken from ridges number five and six in each plot for determining mature pod numbers and dry weights. Ridge numbers seven and eight were manually harvested and sun-dried to determine the following yield components.

1. Pod yield (kg/ha)
2. Hay yield (kg/ha)
3. 100 - Seed weight (g)
4. Shelling percentage: ratio of seeds to total pod weight
5. Harvest index: pod yield divided by total dry matter yield in percent

Results and Discussions

Soil Moisture Content

Table 3 shows the soil water at 20, 40, and 60 cm depth for seasons 2021/2022 and 2022/2023. The table indicates that moisture content increases with depth increase due to increased depletion levels by the increase in the intensity of small roots towards the soil surface in the two seasons. Table 3 indicates that the depletion level increases by increasing irrigation interval at all depths. These results are in agreement with the results given by Syed Abul Hassan and Vaidyanathan (2019) for crops grown in clay soils.

Table 3: Average soil moisture content (% w/w) for the different treatments at different soil depths during the 2021/2022 and 2022/2023 seasons

2021/2022					**2022/2023**				
Treatments		Avg. Soil Moisture			Treatments		Avg. Soil Moisture		
Interval	Total Water	Soil depth (cm)			Interval	Total Water	Soil depth (cm)		
(days)	mm/season	20	40	60	(days)	mm/season	20	40	60
7	2046	26.2	29.5	29.9	7	1860	25.1	27.6	30.5
14	1209	18.5	19.0	19.4	14	1116	20.2	19.3	18.6

21	1023	12.9	16.9	17.2	21	930	13.7	16.2	17.5
28	837	12.0	15.3	15.7	28	744	13.3	16.3	17.2

Water Use Efficiency (Kg/M^3)

The water use efficiency (kg/m^3) data given in Table 4 reveals that treatment 14- and 21-day intervals resulted in the highest efficiency in reason (2022/2023), which may be attributed to weather conditions resulting in relatively higher yields.

Table 4: Water use efficiency of different water quantities treatments during 2021/2022 and 2002/2023 seasons.

Treatments	**Total Seasonal Applied Water (M^3/Ha)**		**Total Seed Yield (Kg/Ha)**		**Water Use Efficiency (Kg/M^3)**	
Interval (days)	2021/2022	2022/2023	2021/2022	2022/2023	2021/2022	2022/2023
7	18600	17670	6096	10118	33	57
14	12090	11160	3777	6770	31	61
21	10230	9300	3102	5598	30	60
28	8370	7440	2074	3536	25	48

Plant Growth and Yield Attributes.

The crop growth attributes measured from each sample are stem plant height (cm), number of pods per plant, plant dry matter production (g/plant), and leaf area index.

i. *Main Stem Plant Height (Cm):* Table 5 shows the variation of plant height (cm) by irrigation interval and time from planting (weeks) for 2021/2022 and 2022/2023. The table indicates that, for both seasons, plant height was significantly reduced as the irrigation interval was prolonged. Increasing the irrigation interval from 7 days to 28 days results in reducing the plant height after 21 weeks from sowing by 41, and 48% for seasons 2021/2022 and 2022/2023, respectively. These results agree with Ibrahim et al (2021) and Singh et al. (2013). Variation in plant height with different irrigation intervals increases with time from the non-significant level in the 8th week to a highly significant level after 21 weeks for both seasons.

Table 5: Variation of plant height (cm) by irrigation interval and time from planting (weeks) for 2021/2022 and 2022/2023

A. Season 2021/2022								
Treatment	Plant Height (Cm)							
	Time (Weeks from Planting)							
Interval (days)	8.0	10	12	14	16	18	21	% Reduction rate after 21 weeks
7	14.0	17.3	19.1	20.2	21.2	23.2	26.1	0
14	13.5	14.0	15.1	17.3	21.1	22.1	22.9	12
21	12.0	13.2	14.8	15.4	16.1	17.1	17.6	33
28	10.1	12.4	13.2	13.6	14.0	14.6	15.4	41

Significance difference	Non-sig	sig	sig	sig	sig	sig	sig	

B. Season 2022/2023								
Treatment	Plant Height (Cm)							
	Time (Weeks from planting)							
Interval (days)	8	10	12	14	16	18	21	% Reduction rate after 21 day
7	15.1	19.3	22.4	28.3	31.3	30.3	31.8	0
14	13.1	14.8	19.3	19.6	22.4	22.7	23.9	25
21	12.5	13.5	14.9	17.3	16.5	17.4	19.5	39
28	12.0	11.4	14.2	14.7	16.3	16.1	16.5	48
Significance difference	Non-sig	sig	sig	sig	sig	sig	sig	

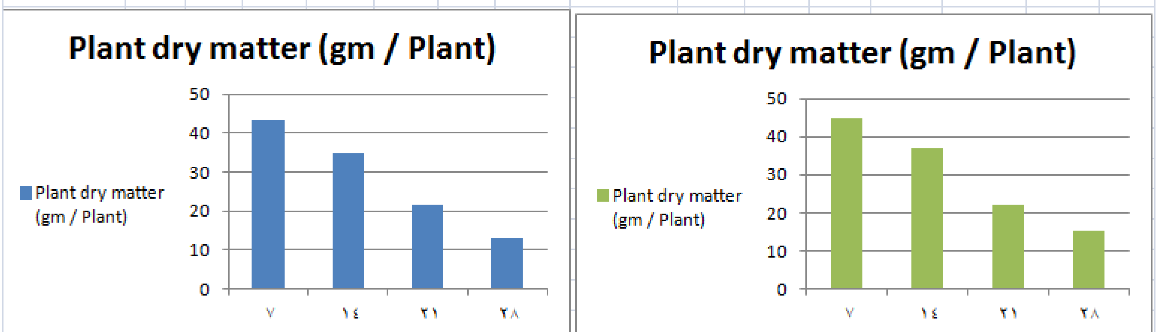
ii. *Number of Pods Per Plant*: The number of pods per plant as affected by the studied irrigation intervals during the first and the second seasons are depicted in Table 7 A, and B. Pod formation was observed in all treatments at the fourth week from sowing and increased continuously with time at reducing increment rate as irrigation interval increased. Ishag et al. (1985) attributed the reduction in the number and dry weight of pods to the failure of pegs to penetrate the soil dry surface. Pod number per plant shows a negative relation with increasing irrigation intervals (Banavath et al .2018, Reddy et al .2003, Singh et al 2013, Ibrahim et al 2021, Reddy et al. 2003). The rate of reduction in the number of pods per plant after 21 weeks from sowing during 7-day intervals compared to 28-day intervals is 75% in each season (Table 6).

Table 6: Effects of increasing irrigation intervals on the number of pods per plant

A- 2021/2022								
No of Pods / Plant								
Treatment	Time (Weeks from planting)							
Interval (days)	4	6	8	10	12	14	16	% Reduction rate after 21 days
7	4.3	12.7	15.7	21	24.3	28.3	30.3	0
14	2.7	7.0	12.3	15.0	20.0	21.3	23.0	24
21	2.0	3.3	5.3	6.3	9.3	13	14.7	51
28	0.0	3.0	3.7	5.3	5.0	6.0	7.7	75
Significance of difference	ns	ns	sig	sig	sig	sig	sig	

B- 2022/2023								
No of Pods / Plant								
Treatment	Time (Weeks from planting)							
Interval (days)	4	6	8	10	12	14	16	% Reduction rate after 21 days
7	4.7	13.0	16.0	21.7	25.0	29.0	31.0	0
14	2.7	7.3	12.7	15.3	20.3	22.0	23.7	24
21	2.0	3.7	5.7	6.7	9.7	13.3	15.0	52
28	0,0	3.3	4,0	5.7	5.3	6.3	8.0	74
Significance of difference	ns	ns	sig	sig	sig	sig	sig	

iii. *Plant Dry Matter Production* (gm per plant): Figure 1 shows that increasing irrigation interval results in a significant reduction of plant dry matter production (shoot and pod weight in gm per plant) with time. The figure shows that dry matter production (g/plant) is reduced as the interval is extended. This agrees with Banavath et al (2018), Reddy et al (2003), and Singh et al (2013) and Ibrahim et al (2021).



Treatment	time (Weeks from planting)							Treatment	time (Weeks from planting)						
Interval (days)	8	10	12	14	16	18	21	Interval (day	8	10	12	14	16	18	21
7	7.4	16.1	25	33.1	35	42.3	43.6	7	7.9	19.6	28.5	35	37.6	43.4	45
14	6.8	13.1	22	27	29	33	34.8	14	7.6	13.4	22.6	27.5	30.5	34.7	36.8
21	5.6	7.9	16.5	14.9	18.5	18	21.8	21	6.5	9.7	17.1	18.2	21.8	20.4	22
28	5.5	7	10.6	12.4	16.4	15.2	13.1	28	6.2	9.3	13.9	16.7	20.3	18.7	15.5

Figure 1: Effect of variation of irrigation intervals on plant dry matter (gm / Plant) with time for season 2021/2022 and season 2022/2023

iv. *Leaf Area Index (LAI):* determined by total leaf area (leaf length by maximum width) to total ground area. Table 7 gives the effects of watering intervals on LAI for the first and second seasons. The table illustrates the progressive increase in LAI with the advancement of crop age. This agrees with Banavath et al (2018), Reddy et al (2003), Singh et al (2013), and Ibrahim et al (2021) With frequent watering every 7 days, LAI reached a maximum value of 6.4 and 6.2% after 18 weeks from crop sowing for seasons one and two, respectively. For the longest watering interval of 28 days, LAI reached a maximum value of 3.6 and 2.6% earlier, after 12 weeks from crop sowing for seasons one and two, respectively. These low and early sessions of LAI are expected to indicate the achievement of reduced production of dry matter.

Table 7: of watering intervals on LAI for first and second seasons.

2021/2022 – Leaf Area Index						
Treatment	Time (Weeks from Planting)					
Interval (days)	8	10	12	14	16	18
7	2.4	3.9	5.1	5.5	6.1	6.4
14	2.1	2.8	4.3	4.5	4.7	5.1
21	1.7	2.3	3.6	3.9	3.9	4.0
28	1.6	2.8	3.6	3.6	3.6	3.6
Significance difference	ns	ns	Ns	ns	ns	ns

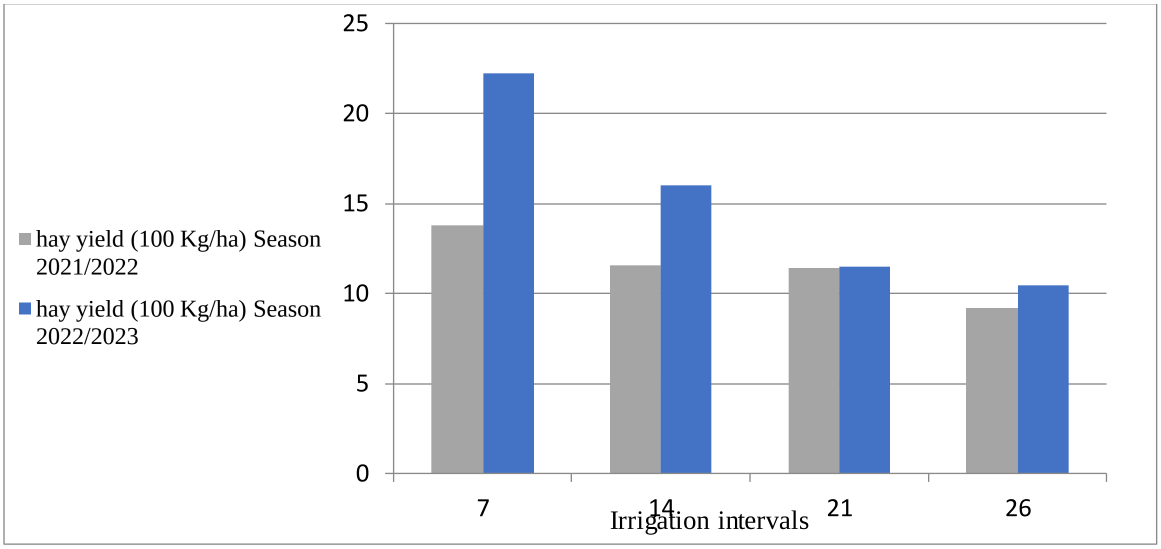
2022/2023 - Leaf Area Index						
Treatment	Time (Weeks from Planting)					
Interval (days)	8	10	12	14	16	18
7	2.4	3.7	5.1	5.4	5.9	6.2
14	2.0	2.9	4.2	4.6	4.8	5.3
21	1.6	1.9	3.1	3.3	3.4	3.7
28	1.5	1.7	2.6	2.6	.2.6	2.6
Significance difference	ns	ns	Ns	ns	ns	ns

Yield Components

These include Pod yield (kg/ha): Hay yield (kg/ha): 100 - 100-seed weight (gm), Shelling percentage, and Harvest index

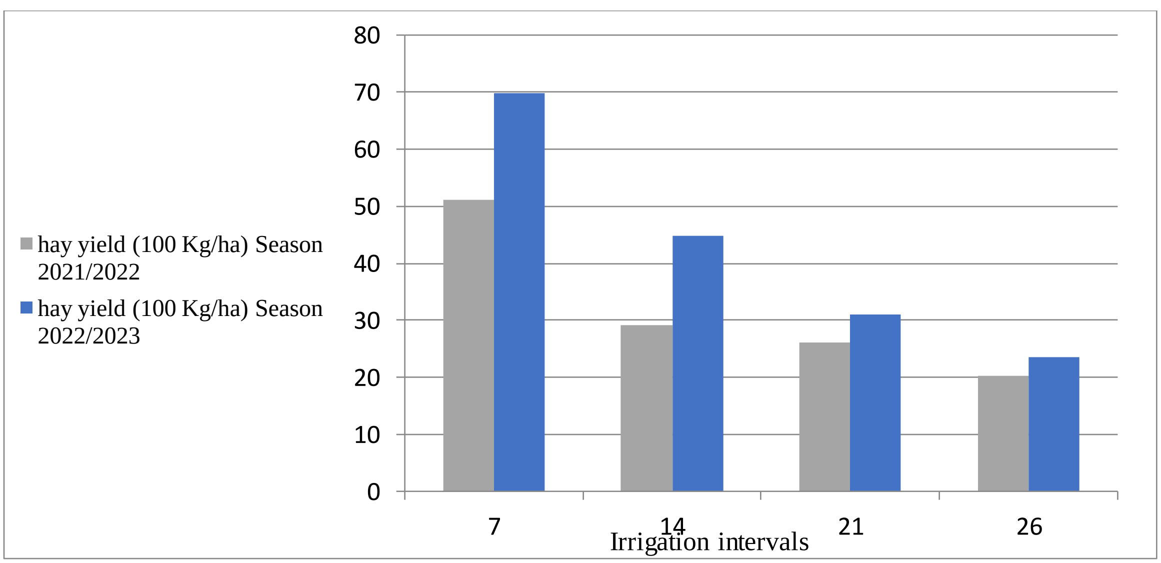
i. *Pod Yield (100 Kg/Ha):* Table 8 shows the impact of irrigation intervals on pod yield (100 kg/ha) for 2021/2021 and season 2022/2023. It is evident from the table that pod yield is significantly affected by prolonging irrigation interval with a negative relation. These results confirm the results given by Banavath et al (2018), Reddy et al (2003), Singh et al (2013) and Ibrahim et al (2021). The pod yield produced in the second season is higher than that obtained in the first season for every irrigation interval. This may be attributed to the dry conditions prevailing during the season. Extending the irrigation interval from 7 days to 14, 21, and 28 days has resulted in yield reduction of 16,17, and 23% for season 2021/2022 and 28, 48, and 53 % for season 2022/2023. Ishag et al. (1985) confirms and smaller difference between 7, 14, and 21 intervals and a high reduction rate when prolonged interval is employed. However, Singh et al., (2013) argue that high humidity due to frequent watering by brief interval intervals of 7-day enhanced flowering and peg formation

Table 8: Effect of increasing irrigation interval on pod yield (100 kg/ha)



Hay yield (kg/ha): As given in Table 9 hay yield decreases with increasing irrigation intervals. The values obtained in the second season are higher than those produced in the first season. This result is in agreement with those obtained for pod yield. The high hay yield obtained by 7-day intervals inboth seasons is attributed by Singh et al. (2013) to stem elongation and increased size of plants and leaves. Extending the irrigation interval from 7 days to 14, 21, and 28 days has resulted in a hay yield reduction of 43,49 and 61% for season 2021/2022 and 36, 56, and 66% for season 2022/2023. According to ICRISAT. 2012), Banavath et al (2018), Sui et al (2015), Ibrahim et al (2021), and Reddy et al. (2003) the pod yield is more sensitive to water stress than hay yield.

Table 9: Effect of increasing watering rate on hay yield



ii. 100 - Seed weight (g): the impact of irrigation intervals on pod yield (100 kg/ha) for 2021/2021 and season 2022/2023. Table 10 shows the effects of increasing irrigation intervals on 100-seed weight (g) during the two studied seasons. As given in Table 11, there is no significant difference in increasing irrigation interval on 100-seed weight (g) in the two seasons and values of 100-seed weight (g) are reduced only with the longest interval in the second season. However, ICRISAT. 2012), Banavath et al (2018), Sui et al (2015) and Ibrahim et al (2021), reported that pod yield is least affected by changing watering intervals,

Table 10: Effects of increasing irrigation intervals on 100 - Seed weight (gm) during season 2021/2021 and season 2022/2023

Irrigation	**Seed Weight (Gm) - Season 2021/2022**			
Intervals	Replication R1	Replication R2	Replication R3	mean
7	28.93	29.27	29.24	29.15
14	31.07	30.13	31.59	30.93
21	29.83	30.62	29.9	30.12
26	24.52	26.6	24.67	25.26
Irrigation	Seed weight (gm) -Season 2022/2023			
Intervals	Replication R1	Replication R2	Replication R3	mean
7	30.7	30.01	26.12	28.94
14	29.78	30.49	29.98	30.08
21	25.19	24.81	25.63	25.21
26	19.48	21.61	19.81	20.30

iii. Shelling percentage: ratio of seeds to total pod weight. The impact of the variation of irrigation intervals shelling percentage for 2021/2022 and season 2022/2023 is shown in Table 11. The table indicates no significant differences in values of shelling percentage in the two seasons. This result is in agreement with Ishag et al. (1985).

Table 11: The impact of variation of irrigation intervals on shelling percentage for 2021/2021 and season 2022/2023

Irrigation	Season 2021/2022			
Intervals	Replication R1	Replication R2	Replication R3	mean
7	70.39	84.72	67.97	74.36
14	69.55	82.84	69.56	73.98
21	72.24	81.78	68.33	74.12
26	61.78	81.41	61.65	68.28
Irrigation	Season 2022/2023			
Intervals	Replication R1	Replication R2	Replication R3	mean
7	51.43	68.04	67.86	62.44
14	54.77	71.53	71.26	65.85
21	53.97	68.97	54.97	59.30
26	56.2	63.57	62.99	60.92

iv. Harvest index: pod yield divided by total dry matter yield in percent. The effects of variation of irrigation intervals on the Harvest index for 2021/2022 and season 2022/2023 are shown in Table 12. The table shows that no clear variations in harvest index due to changing watering intervals in both seasons, and reduction by increasing irrigation interval more than 7 days is rate is 52-51%. This result is in line with that reported by Banavath et al (2018), Reddy et al (2003), and Singh et al (2013), and Ibrahim et al (2021).

Table 12 The effects of variation of irrigation intervals on harvest index shelling percentage for 2021/2022 and season 2022/2023

Irrigation	**Season 2021/2022**				
Intervals	Replication R1	Replication R2	Replication R3	mean	% yield reduction from 7-day
7	26.62	27.15	35.33	29.70	0
14	26.9	27.45	33.12	29.16	2
21	18.02	18.7	23.56	20.09	32
26	12.16	12.04	18.28	14.16	52
Irrigation	Season 2022/2023				
Intervals	Replication R1	Replication R2	Replication R3	mean	% yield reduction from 7-day
7	25.14	26.34	26.65	26.04	0
14	22.2	22.25	21.39	21.95	16
21	14.78	18.99	18.99	17.59	32
26	10.07	13.92	14.17	12.72	51

From the above discussion, it is evident that prolonging the watering intervals reduced both vegetative and reproductive growth attributes, while frequent watering resulted in improved pod and hay yield. Such reduction is manifested in the number and dry weight of pods per plant. For irrigated groundnut, it is possible to increase field water use efficiency dry matter production, and crop yield, by imposing a transient deficit in soil moisture using 14-day irrigation intervals or even 21day intervals at the time of severe water shortage without significant loss on crop productivity. Research is needed to develop transferable technology to help farmers of arid and semi-arid regions. Increasing soil moisture storage by soil profile management and nutrient management for quick recovery from drought are some of the areas that need to be explored further.

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