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Effect of irrigation systems on the growth parameters of cowpea (*Vigna unguiculata* L. Walp) cultivars in N'Djamena city, Chad

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Abstract

The study was conducted during the winters of 2021 and 2022 at the research farm of the Higher Teachers Training School of N'Djamena, Chad. The aim of the present investigation is to evaluate the growth and productivity traits of four cultivars of cowpea plant (white, black, red, and versicolor) in response to two different irrigation periods (3 and 6 days). The experiment is a factorial with four cowpea cultivars (White, Black , Red and versicolor) in the main plot in a Randomize Complete Block Design (RCBD) and irrigation intervals (3 and 6 days) as the subplot with three replications. Our data demonstrated that the black variety was much superior in leaf surface area (15942.37 cm2), wet weight (343.75 g), dry weight (96 g), number of pods (71.50), weight of pods (137.50 g), number of seeds (475), and total productivity was 2.47 tons/ha. On the other hand, the versicolor variety was superior in the plant height (197 cm), number of leaves (138.75), pod length (15.50 cm), number of seeds in the pod (8.25), while the white variety had the highest average weight for 100 seeds (26.30 g). The same results also, indicated that the irrigation rate for three days was better than that for six days in terms of plant height (162.75 cm), number of leaves (108.37), leaf surface area (12553.72 cm2), wet weight (309.37 g), dry weight (73.25 g), pod length (14.50 cm), weight of seeds per pod (72 g), number of seeds per plant (241.50) and the productivity was 1.29 tons/ha. Finally, the study suggests planting the black and versicolor varieties in N'Djamena city during winter season in order to get the maximum yield by surface irrigation every three days.

Keywords: Growth and productivity traits; Cowpea plant; Irrigation periods; Versicolor

1. Introduction

Leguminosae (*Fabaceae family*) which comes after cereal crops is crucial to the production of food for humans and animals due to its high protein content (Awasha and Nasri, 2016). Globally, the total production of it is about 70.41 million tons in an area of 77.5 million hectares, and it is grown in thirty countries worldwide with a productivity of about 907 kg/ha (Bohra *et al.,* 2014).According to Al-Aqidi (2009), cowpea plant (*Vigna unguiculata* L Walp) is one of the most significant nutritious legumes. Because cowpeas are the primary food legume in the world, they are planted in all tropical regions, and can significantly improve the yield of other agricultural crops (Djirabye *et al.,* 2015). The crop is mostly cultivated for its very nutritious dry seeds, and its green leaves are used for humans in some African countries (Ghaly and Alkoaik., 2014).They are also fed to animals as green fodder (Al-Husseini, 2006). Cowpea plant enhances the properties of the soil because it is able to convert atmospheric nitrogen into nitrogenous compounds then can be used by the plant itself (FAO, 2012).When grown in alternation with other crops, especially in low - fertility areas, it also supplies nitrogen to them, hence reducing the need for chemical nitrogen fertilizers added in soil (Sheachan, 2012). About 80% of world's cowpea production is produced in three major producing nations: Niger, Nigeria, and Burkina Faso (FAOSTAT, 2013). The area cultivated with the cowpea crop in Chad during the last four years, from 2016 to 2020 is 0.22 M/ha with an average productivity of 0.15 tonnes (Department of the Agricultural Statistics and the National

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Authority for Rural Development, 2021). Therefore, using irrigation techniques has become an important issue to face the threat caused by lack of rain in the present and future (Al-Tamimi, 2017). Plants require appropriate amount of water using different ways from the time of planting until they reach full maturity and are harvested (Qandil and Sherif, 2013). Irrigation is an effective process in maintaining high crop production by applying controlled amount of water to crops in order to grow well, and at the same time this helps in lowering the waste of water used for agriculture (Hayati, 2019).In general, adding water to the soil can help in crop growth and increase production by protecting it from drought stress, cooling the soil and the environment surrounding the plant, washing salts out and diluting them from the soil (Masimi, 2016). Salem *et al.,* (2016) mentioned that scheduling and repeating irrigation by drip method has a significant impact on growth and productivity of the cowpea crop in, Samra and Iraq *et al.*, (2015), also reported that certain cowpea varieties differ from each other in terms of growth, quantity and quality of production. Furthermore, Baladia (2013) found a direct correlation between agricultural productivity and water requirements. Practical studies that about the connection between water and agricultural yield confirm that crop production peaks when the water volume is specified and increasing irrigation water more than the specified amount of it leads to a decrease in quantity of production. Jabrouti (2015) demonstrated that the main reason for understanding a plant's water requirements is to provide them with enough water to avoid water stress during vegetative growth and to prevent a reduction in the production and quality of the plant's output. Thus, the time of each irrigation is determined. This makes it possible to better manage and organize the usage of water resources and allows to estimate a daily, weekly, monthly and seasonal water consumption.

2. Material and methods

A field experiment was conducted during the winter months of 2021 and 2022 at the research farm of the Higher Teachers Training School of N'Djamena, Chad, in a coastal and semi-arid area with average daily temperatures ranging from 20°C to 42°C during the dry season, which extends from October to May. The study area is located at longitude (09'' 10' 12˚N) and latitude (18'' 06' 15˚E).The soil used is clay sand in texture (Table 1). Our experiment included two irrigation periods (3 and 6 days) with four local, unimproved varieties of cowpea plant (white, black, red, and versicolor). They were obtained from different regions. The red variety was from Koundoul, the white and versicolor varieties were from Oum Al-Timan, and the black variety was from Pectin region. Only the best cowpea seeds were chosen, and their total number was (432) The experiment is a factorial with four cowpea cultivars (White, Black , Red and versicolor) in the main plot in a Randomize Complete Block Design (RCBD) and irrigation intervals (3 and 6 day) as the subplot with three replicates was used to perform the experiment**.** On 6th January 2022, planting took place in the form of agricultural ponds with an area of $16m^2$ (4m length and 4m width).Each experimental unit was divided into three terraces with a 120cm gap between them, keeping in mind that the total number of experimental units was (24). The ponds were irrigated with tap water until they reached the level of field capacity. The amount of water to be applied in each irrigation treatment was determined based on knowledge of soil moisture content according to weather conditions. We used a gallon with a capacity of (20L) to calculate the quantity of water consumed per the experimental unit. After germinating cowpea seeds, the experiment was split into two periods according to irrigation system. Twelve units, including the four varieties of cowpea, were irrigated every three days, while the other twelve units received irrigation every six days. The irrigation method was used throughout this time until the end of field experiment. Experiment measurements were estimated from four randomly selected plants in the middle rows of each experimental unit. The number of study samples was (96), and the characteristics included plant length, number of leaves, and leaf surface area were measured regularly every two weeks (14 days), but the number of days (100% flowering), number of pods per plant, the length of pods, weight of the dry pods, number of seeds per plant, the dry and wet weight of the plant, weight of the dry seeds per plant, weight of 100 seeds and total productivity per hectare were recorded when the experiment was finished.

3. Results and discussion

It was found that the saturation degree of each experimental unit is approximately (180 L). Table (1) investigated the physical and chemical properties of soil include soil texture, pH, electrical conductivity and available elements.

Table 1 Physical and chemical analysis of soil (National Center for Research in Sudan, 2022)

Soil characteristics (chemical and physical)		**Value**
pH		6.65
Electrical conductivity (EC)		1.32 dSm-3
Nitrogen		69.76 mg kg-1
Phosphorus		20.05 mg kg-1
Potassium		103.50 mg kg-1
Soil textural analysis:	Sand	230 g kg-1
	Silt	150 g kg-1
	Clay	307 g kg-1
Textural class	Clay sand	

3.1. Effects of irrigation treatments on plant length (cm), number of leaves, and leaf surface area (cm^2)

Our results in Table (2) showed highly significant differences in plant length between the varieties under study. The versicolor variety recorded the highest length (197 cm), followed by the black and white varieties, which recorded an average length of 166 and 125.5 cm, respectively, while the red variety recorded the lowest length (85 cm).Table (2) also, appeared that the three days irrigation treatment was superior to the six days irrigation treatment. The three days irrigation treatment gave the highest plant length (162.75 cm), but the six days irrigation treatment gave the lowest length (125 cm). The three days irrigation treatment recorded an increase in plant length by 30.20% compared to the irrigation treatment every six days. The reason for these difference in plant length between cowpea varieties may be attributed to genetic or environmental factors, and this difference helps in knowing the varieties required for cultivation according to the need, these result are consistent with those of (Samra *et al.,* 2015; Al-Karkhi, 2017; Al-Anbari, 2014). In Table (3), it was noted that the highest number of leaves (138.75 L/P) was recorded by the versicolor variety, and thus was significantly superior to the other varieties like the black variety, which produced (108 L/P) followed by the white and red varieties that recorded the lowest number of leaves (75.50 and 72.50 L/P, respectively). These results are in line with the results of Mohammed (2016) and Samra *et al*., (2015) in their study of mung and cowpea crops. The irrigation treatment every three days was superior to irrigation that was applied every six days in the number of leaves. In case of three days irrigation treatment, the number of leaves was 108.37 L/P, while the irrigation that was every six days recorded 89 leaves per the plant. The variation in the number of plant leaves may be due to genetic factors as observed by Al-Fahdawi *et al.,* (2015). There were significant differences between the studied varieties in the leaf surface area of the plants. The black and versicolor varieties recorded the highest values for this trait (15942.37 and 14399.45 cm^2, respectively), while the red and white varieties recorded the lowest leaf surface area (6772.5 and 5682.5 cm^2, respectively) (Table 4).

Table 2 Effects of different irrigation treatments on plant length (cm)

Cowpea varieties	**Irrigation treatments**		**Mean**
	3-day	**6-day**	
White	140	115	127.5
Black	193	139	166
Red	86	84	85
Versicolor	232	162	197
Mean	162.75	125	
LSD (0.05)	1.13		

This may be as a result of vegetative growth nature and genetic characteristics of the varieties as was found by Samra *et al.*, (2015).The three days irrigation treatment outperformed the six days treatment by giving the highest leaf surface

area of the plant (12553.72 cm^2). The decrease in leaf surface area of plants that were irrigated every six days may be due to water stress as was recorded by Al-laila (2012) in the research of sunflower and mung plants.

Table 3 Effects of different irrigation treatments on number of leaves (L/P)

Cowpea varieties	Irrigation treatments		Mean
	3-day	6-day	
White	82	69	75.5
Black	122	94	108
Red	75	70	72.5
Versicolor	154.5	123	138.75
Mean	108.38	89	
LSD (0.05)	5.36		

Table 4 Effects of different irrigation treatments on leaf surface area (cm^2)

Cowpea varieties	Irrigation treatments		Mean
	3-day	6-day	
White	6707.5	4657.5	5682.5
Black	18528.75	13356	15942.37
Red	7250	6300	6775
Versicolor	17728.9	11070	14399.45
Mean	12553.72	8845.87	
LSD (0.05)	1.13		

3.2. Effects of irrigation treatments on the number of days (100% flowering), number of dry pods per plant, the length of pod (cm)

There were no significant differences between cowpea varieties under study in the number of days (100% flowering). The white, red and black varieties flowered within 71, 73 and 74 days since the beginning of planting them, while the versicolor variety flowered late within 78 days .As shown in Table (5), the three days irrigation treatment was superior to six days irrigation treatment. This may be because of the plant length (Table 2), the number of leaves (Table 3), and the leaf surface area of the plants (Table 4). The black variety outperformed all the other varieties in number of pods per the plant (71.50). (Table 6).The number of pods was 24 and 18.50 per red and white varieties, respectively. The increase in the number of pods is related to genetic properties of variety. The same outcomes was detected in both studies of Samra *et al.*, (2015) and Saeed *et al.,* (2019). The irrigation treatment every three days and six days recorded an average number of pods per plant (33 and 31.50, respectively). This is according to reports that written by Salem *et al.*, (2016) and Al-Karkhi (2017). The versicolor and white varieties recorded an average pod length (15.5 and 15 cm), respectively (Table 7).While, the red variety had a decrease in pod length by 12.90 and 10% compared to versicolor and white varieties. The researches of (Al-Assafi and Abd 2014; Samra *et al*., 2015) explained that the genetic characteristics of the variety and its influence by the environmental factors can cause the difference in the pod length between the plants under study.

Table 5 Effects of different irrigation treatments on the number of days (100% flowering)

Cowpea varieties	Irrigation treatments		Mean
	3-day	6-day	
White	74	68	71
Black	78	70	74
Red	76	70	73
Versicolor	83	73	78
Mean	77.75	70.25	
LSD (0.05)	3.32		

Table 6 Effects of different irrigation treatments on the number of dry pods per plant

Cowpea varieties	Irrigation treatments		Mean
	3-day	6-day	
White	22	15	18.5
Black	73	70	71.5
Red	21	27	24.0
Versicolor	16	15	15.5
Mean	33.00	31.75	
LSD (0.05)	0.83		

Table 7 Effects of different irrigation treatments on the length of pods (cm)

Cowpea varieties	Irrigation treatments		Mean
	3-day	6-day	
White	15	15	15.0
Black	13	11	12.0
Red	14	13	13.5
Versicolor	16	15	15.5
Mean	14.50	13.50	
LSD (0.05)	0.97		

3.3. Effects of irrigation treatments on the weight of the dry pods, number of dry seeds per plant and the number of seeds per pod

The black variety was significantly superior to the other varieties by producing the highest weight of the dry pods (137.5 g/p), while there were no significant differences between the white and red ones, as they recorded an average weight of dry pods (46.50 and 46 g/p, respectively) with a decrease by 66.18 and 66.54% compared to the black variety, respectively. Versicolor variety recorded the lowest weight of dry pods (45.50 g/p) (Table 8).These results were close to those found by Al-Assafi and Abd (2014). For the characteristic of seeds number per plant, we found thatthe black variety outperformed the other varieties and recorded an average number of seeds (475 seeds/plant) followed by the red variety which recorded an average number of seeds (185.50 seeds/plant) (Table 9) with a decrease of 60.94%

compared to the black variety, while the white and versicolor varieties recorded the lowest average number of seeds (132 and 127.50 seeds/plant, respectively). These results corroborate with research conducted by (Samra *et al.,* 2015 and Al-Anbari, 2014). There was no significant effect on the number of seeds per the pod between the three and six days irrigation treatment. Table (10) showed that the three and six days irrigation treatment recorded an average number of seeds in the pod as 7.75 and 7.37 seeds/pod, respectively. Similarly, (Hanshal and Al-Bayati, 2016; Al-Karkhi, 2017) said that the reason for this difference is due to the formation of the pods versus the number of seeds.

Table 8 Effects of different irrigation treatments on the weight of the dry pods (g/p)

Cowpea varieties	**Irrigation treatments**		**Mean**
	3-day	**6-day**	
White	54	39	46.5
Black	153	122	137.5
Red	39	53	46
Versicolor	42	47	45.50
Mean	72	65.25	
LSD (0.05)	0.39		

Table 9 Effects of different irrigation treatments on the number of dry seeds per plant

Cowpea varieties	**Irrigation treatments**		**Mean**
	3-day	**6-day**	
White	154	110	132.0
Black	530	420	475
Red	148	223	185.5
Versicolor	134	121	127.5
Mean	241.5	218.5	
LSD (0.05)	3.13		

Table 10 Effects of different irrigation treatments on the number of seeds per pod

Cowpea varieties	**Irrigation treatments**		**Mean**
	3-day	**6-day**	
White	7.0	9.0	8.0
Black	7.0	6.0	6.5
Red	7.0	8.0	7.5
Versicolor	8.5	8.0	8.25
Mean	7.37	7.75	
LSD (0.05)	0.31		

3.4. Effects of irrigation treatments on the weight of 100 seeds (g), dry and wet weight of the plant (g), and total productivity (ton/ha) of cowpea varieties

Table (11) indicated that there was no significant effect of irrigation treatments on the weight of 100 seeds. The three and six days irrigation treatments achieved an average weight of 100 seeds (23.50 and 22.41 g, respectively). This study agreed with the results of (Al-Karkhi, 2017 and Salem *et al.,* 2016) in studying the mung and cowpea crops, respectively. On the other hand, the irrigation treatments had a significant effect on the wet weight of cowpea crops (Table 12). It was noted that the black variety recorded (381.50 g/p) at the irrigation treatment every three days, and (306 g/p) was recorded at the six days treatment with a decrease of (19.79%). This also discussed in the report of Hassan and Ali (2010). The dry weight of the varieties was high at the three days irrigation treatment (73.25 g/p) with an increase by 84.27% compared to the six days treatment, which recorded the lowest average dry weight (39.75 g/p) (Table 13) with a decrease of (45.73%).The difference in dry weight may be due to the space between irrigation periods and environmental factors as verified by (Hashim, 2018; Raw and Shahid, 2011) in their study of mung, cowpea and guar crops, respectively. Table(14) confirmed the presence of a significant effect of the varieties in increasing the total production of cowpea plant per hectare. The effect of the black variety was clear as it recorded the highest value (2.47 ton/ha), while the production value decreased significantly for the other varieties. The Red and white varieties produced 0.88 and 0.84 ton/ha, respectively, with a decrease of 64.40 and 65.72%, respectively, and the versicolor variety recorded the lowest production (0.76 ton/ha) with a decrease by 9.52, 13.63, and 69.23% compared to the other varieties under study, respectively (Table 14). The results in table (14), also concluded the effect of irrigation treatments on the production of cowpea crop, as the three days irrigation treatment achieved the highest production (1.29 ton/ha) and was significantly higher than the six days treatment, which recorded (1.18 ton/ha) with a decrease of (8.38%). Perhaps, the increase in the total production per hectare is due to the increase in the number of pods (Table 9), as well as the increase in the weight of pods (Table 10). This result goes with the study of (Samra *et al.,* 2015 and Al-Anbari, 2014).

Table 11 Effects of different irrigation treatments on the weight of 100 seeds (g)

Cowpea varieties	Irrigation treatments		Mean
	3-day	6-day	
White	27.0	25.6	26.30
Black	22.0	21.04	21.52
Red	20.0	19.0	19.50
Versicolor	25.0	24.0	24.50
Mean	23.50	22.40	
LSD (0.05)	0.26		

Table 12 Effects of different irrigation treatments on the wet weight of the plant (g)

Cowpea varieties	Irrigation treatments		Mean
	3-day	6-day	
White	278.50	157.50	218.0
Black	381.50	306.00	343.75
Red	202.50	200.00	201.25
Versicolor	375.00	300.00	337.50
Mean	309.37	240.87	
LSD (0.05)	6.25		

Table 13 Effects of different irrigation treatments on the dry weight of the plant (g)

Cowpea varieties	Irrigation treatments		Mean
	3-day	6-day	
White	50	39	44.5
Black	102	90	96
Red	40	39.5	39.75
Versicolor	101	70.5	85.75
Mean	73.25	59.75	
LSD (0.05)	3.02		

Table 14 Effects of different irrigation treatments on the total productivity of varieties (ton/ha)

Cowpea varieties	Irrigation treatments		Mean
	3-day	6-day	
White	1.01	0.68	0.84
Black	2.70	2.24	2.47
Red	0.68	1.08	0.88
Versicolor	0.78	0.73	0.76
Mean	1.29	1.18	
LSD (0.05)	0.035		

4. Conclusion

The black variety's adaptation and its resistance to harsh weather, particularly during the winter, led to an improvement in growth characteristics, but the versicolor variety was less productive, despite having a higher value for each plant length and number of leaves. Even though the maturity time is delayed, the cowpea crop grows and produces better when the process of water stress is reduced. The soil used for the experiment is regarded as one of the best for the growth and productivity of the black and versicolor cultivars.

Recommendations

Based on current findings, our study recommends the following:

- Moving towards cowpea cultivation through irrigation in order to reduce the impact of winter agricultural pests.
- Focus on growing the cowpea that is more tolerant to the environmental changes and has economic importance.
- Growing the black and versicolor cultivars as forage crops to reduce overgrazing and provide food for livestock.
- Increasing cowpea cultivation in Chad, as it suffers from the high cost of animal proteins.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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