https://doi.org/10.46344/JBINO.2024.v13i06.04

STUDY EFFECT OF SOIL AND WATER ON POTATO PRODUCTION IN IRAN DESERT CONDITION

Hamid kheyrodin
Assistant professor- semnan university- Iran
Mail:hamid.kheyrodin@semnan.ac.ir

ABSTRACT

In this study, the cultivation substrate was the main factor (sandy, clay, compost) and drought stress in four control levels and -0.3, -0.6, -1, and -1.5 MPa of soil water potential in three replicates in the form of a split plot. will comeThis study was conducted at the Experimental Farm of the faculty of desert of Semnan University located in Iran during the winterand spring seasons of 2004. First, the physical and texture properties of soils, chemical properties and exchangeable ions, and some biochemical properties of enzymes such as urease are measured. Duncan's test will be used under SPSS conditions to compare the means and relationships between growth components and the effects of drought stress. The evaluated traits include potato yield, plant height, number of plant branches, number of tubers per plant, potato tuber weight average, tuber size, and production leaf area. The results have shown that the evaluated traits are significantly influenced by the type of soil texture. , and water stress and the mutual effect of these two factors. So, under non-limited water resources conditions, clay sand produces the highest yield under full irrigation but water-saving irrigations are not recommended due to considerable loss (50%) in potato yield.

Keywords: Potato, Soil texture, Drought stress, Potato physiology

1. Introduction

China maintains its position as the world's largest potato producer, boasting a remarkable output of 99.2 million tonnes in 2021. Its favorable climate and fertile land provide an optimal environment for potato cultivation, a tradition dating back over 400 years to the Ming Dynasty. With diverse landscapes, ranging from cold and dry in the north to warm and wet in the south, China can cultivate potatoes year-round. Leveraging cutting-edge technology and improved seed varieties, China maximizes efficiency in potato farming, ensuring a bountiful harvest year after year. Potatoes are one of the world's most popular and versatile crops, loved by people all over the globe. They are a staple food in many countries and are used in a variety of dishes. In this article, we will take a look at the top 10 potato-producing countries in the world and explore why they are leading the way in potato production

India is the second-largest producer of potatoes, with a production of 48.2 million tonnes in 2021. Potatoes are an essential crop in India, used in traditional dishes such as aloo paratha and samosas, making it an integral part of the country's cuisineBeukema. and van der Zaag. (1979). The Portuguese brought potatoes to India in the early 1600s.But it wasn't until the 1800s that people started growing potatoes to sell.In the 1960s, when there was a big change in farming called the Green Revolution, India started growing a lot more potatoes.India has different kinds of weather, from really hot to kind of cool, which is great

growingpotatoes.

Potato with the scientific name Solanum tuberosum is a plant from the eggplant family that has compound and cut leaves and white or purple flowers. Its fruit is small, spherical, red, round and poisonous. Potato is the fourth most cultivated agricultural product in the world after corn, wheat and rice(University of Wisconsin 2005)-.

Potato production in the world has increased from 270 million tonnes in 1961 to 370 million tonnes in 2019. The increase in production is primarily because of a consistent increase in yield potential of potato cultivars, as the area harvested for potato production decreased from 22.14 million hectares to 17.34 million hectares in the same period. The yield potential of potato cultivars has increased by 58.7% in the last half-century . China, India, Russia, the USA, and Ukraine are the largest potato-producing countries, followed by Poland, Germany, Belarus, Netherlands, and France. Europe is the second-largest potato-producing region (125.43 million tonnes) after Asia (140.6 million tonnes) figure 1..

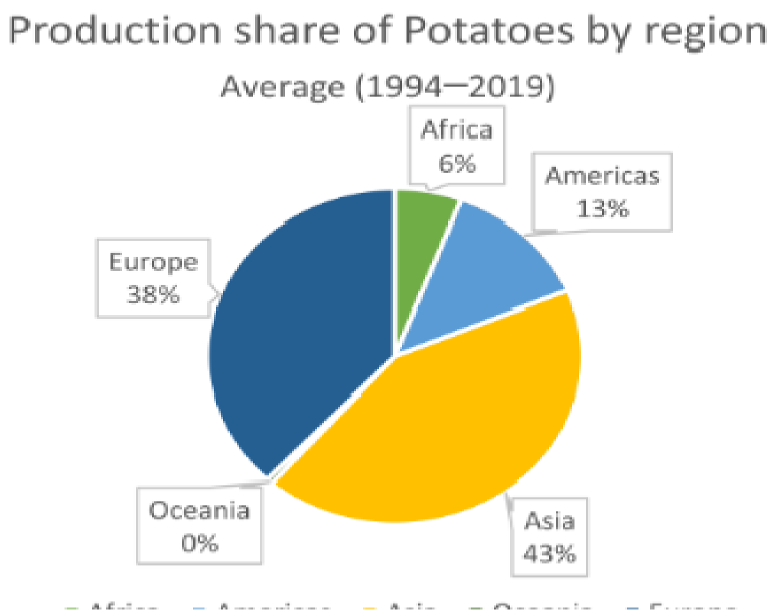

Figure 1: Regional share in potato production during 1994–2019 (FAO 2021)

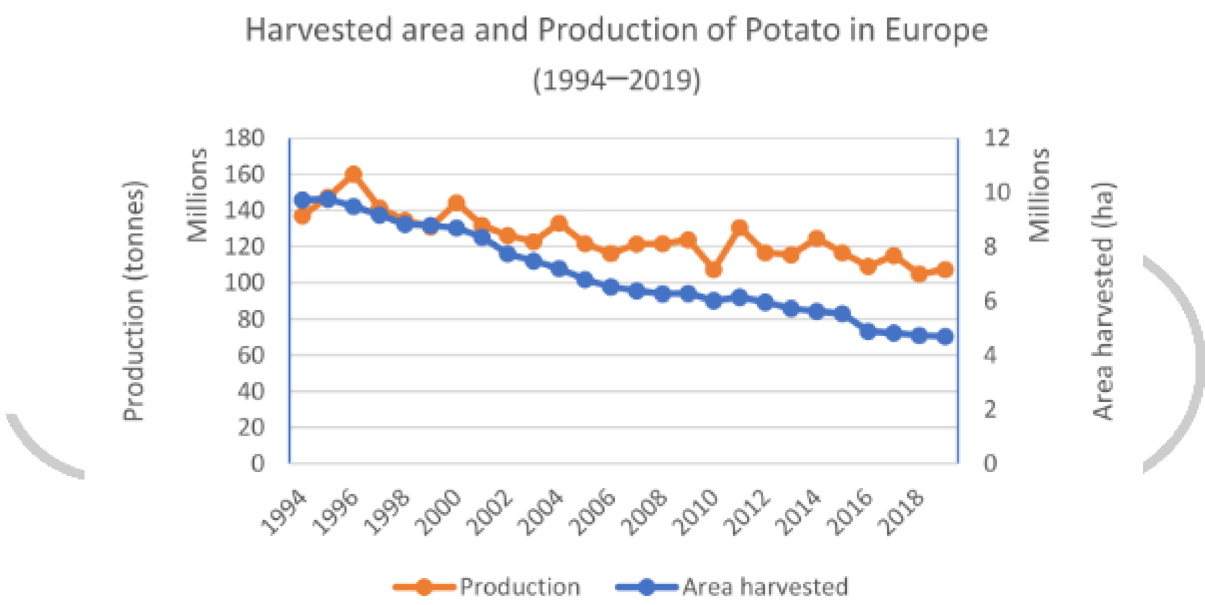

Figure 2: Potato production and area allocated for potato harvest in Europe during 1994–2019(FAO 2021).

In Europe, potato production has reduced from 137.1 million tonnes in 1994 to 107.26 million tonnes in 2019. The highest potato production in Europe was observed during 1996, and has been declining ever since. The main reason for the decrease in tuber production in Europe is the reduction in the harvested area by 51.7% between 1994–2019. In 1994, potatoes were harvested on 9.7 million ha of European land; however, in 2019, only 4.69 million ha of land was used for potato production. Recent FAO stats show [4] that most of the potato production in Europe comes from Eastern Europe (55–61%), followed by Northern Europe (25–29%). Southern Europe and Western Europe contribute only 6% and 10%, respectively

The potato tuber is a non-photosynthetic organ whose performance depends on the activities of the source and reservoir and genetic factors, leaf area index, fertilization, temperature, soil (physical, chemical and biological properties), light intensity and humidity are involved in it. and have mutual and sometimes misleading effects. The root of the potato plant is scattered and 85% of it is located at a depth of 30 cm, and for this reason, it is sensitive to drought stress and requires sufficient moisture in the light soil during the entire growth period(Harris1978). Drought stress occurs in the plant when the potential evaporation and transpiration (atmospheric evaporation demand of the plant) exceeds the actual evaporation and transpiration (the capacity and ability of the roots to extract water from the soil). Experiments by scientists have shown that drought stress up to 80 percent of the plant's water requirement, both before and after tuber formation, causes significant differences in potato production. The tuber bulking stage is one of the important stages of potato growth. At this stage, the plant invests most of its resources on newly formed tubers. At this stage, several factors are very important to get a good product. Among them are optimal soil moisture and temperature, availability of sufficient nutrients in the soil and their balance, and resistance to pest and disease attacks. The maturity stage of the tubers is very important for the food. Potatoes contain toxic compounds called glycoalkaloids. The most important of these poisons are solanine and chaconine. Solanine in potato is determined by the appearance of green color, especially in the cortex under its skin, which is necessary to study it in many soil tissues. Identification, determination and analysis, reserve root performance and shoot fresh weight, number of leaves, number of branches, reserve root weight, reserve root diameter, plant length and reserve root length are of particular importance (Ackerson et 1977).Ackerson, R.C., D.R. Krieg, T.D. Miller and R.G. Stevens. 1977The importance of the potato as a food source and culinary ingredient varies by region and is still changing Fig 1: Show botanical composition of potato. It remains an essential crop in Europe, especially Northern and Eastern Europe like the tomato, the potato is a nightshade in the genus Solanum, and the vegetative and fruiting parts of the potato contain the toxin solanine which is dangerous for human consumption. Normal potato tubers that have been grown and stored properly produce glycoalkaloids in negligible amounts, but, if green sections of the plant (namely sprouts and skins) are exposed to light, the tuber can accumulate a high enough concentration of glycoalkaloids to affect human health.

2.Experimental setup

An experiment was conducted during 20 december 2023 through March 2024 to assess the effect of planting dates on growth and yield performance of three potential varieties of potato at Semnan university . The experiment was laid out in a randomized complete block design with three replications.

In this experiment, seed tubers of potato plants are cultivated in soils with different textures in special plots in March. In this research, the effect of different levels of water stress on yield up to tuber size, percentage of dry matter and number of aerial stems, tuber length, tuber diameter, number of potato tuber are investigated in a split plot design with 3 replications. One of the methods of studying the effects of external factors of heat, humidity, cultivation environment, fertilizers and poisons on photosynthesis is by measuring chlorophylls (a, b) and total carotenoids. In this method, one gram of fresh sample of potato leaves is crushed and ground and mixed and homogenized using 10 ml of 80% acetone. One milliliter of it is selected and mixed with 9 milliliters of 80% acetone and centrifuged for 15 minutes at a speed of 8000 revolutions per minute. Then the supernatant phases are separated to measure chlorophyll a and b and carotenoids. The rest of our work is experimenting with a UV spectrophotometer method. Chlorophyll A and B and total carotenoids are determined at wavelengths of 663, 645, and 480 nm. Acetone 89% is used as blank and control (white) and the amount of chlorophylls is calculated from the Arnon equation. The amount of carotenoid is calculated using the Gross equation in 1991. Also, the components, number, length and diameter of the potato tuber and the amount of dry matter of the tuber are determined. Identifying the mutual effects of tissue and culture medium and water stress on average tuber weight, tuber size, number of tuber per plant, number of branches per plant, plant height are among the things that have not been studied at the province level and should be studied. Also, what effect do changes in the concentration and amount of NPK elements, soil texture and water stress have on the quantity and quality of potato texture (kheyrodin, 2006). We measured environmental, physiological, and hydrodynamic parameters, specially at times of water stress, to assess the impact of such stress on the plant. Environmental parameters, such as air temperature and humidity, wind speed, and solar radiation were measured to maintain favorable conditions to potato (Solanum tuberosum, L.) production. The measured hydrodynamic variable is soil matric potential and is used to trigger and stop irrigation according to the imposed stress level and durationDavies (1977).

Stomatal conductance

We manually measured stomatal conductance on the same leaf during the entire production cycle. We performed the measurement for all experimental units on the third leaf from the top of the plant stem starting at 11:00 a.m. through 1:00 p.m. using an AP4 porometer. This method provides a measurement to evaluate the time it takes for a leaf to release enough water vapor to bring the humidity of the instrument's air chamber to a fixed value according to cropping objectives and conditionsBarrs (1968). .

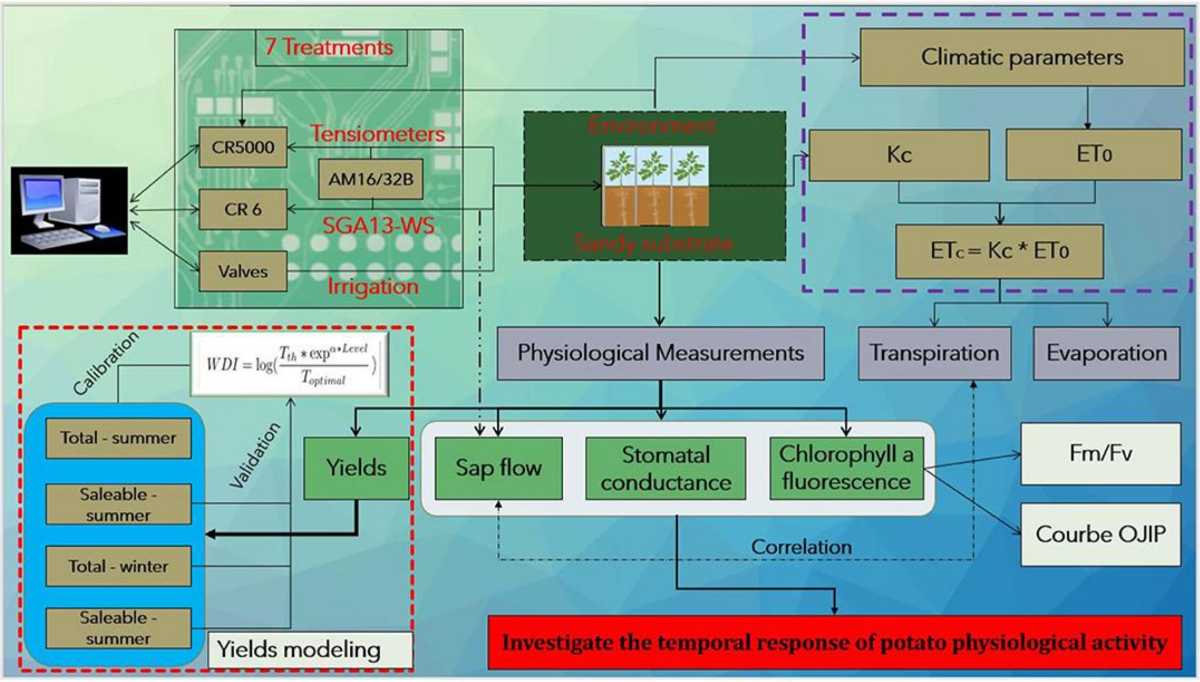

Figure 3: Summary of the methodology applied in the paper.

Figure 4. : Potato cultivar experiment in green hous in Semnan university

3. Results

Analysis variance of the effects of soil texture and water stress on the growth of potato aerial parts present in table 1and 2. Fig 2 has shown that drought stress has a tremendous impact on potato production and its impact depends on the severity and duration of the stress and on the crop growth stage as well. The table 2 shows the growth stages and the amount of available water required for a high yield of high-quality potatoes. Soil moisture should be above 70 per cent for all stages stress becomes critical when the available soil water drops below 65 per cent.

This research is carried out in the winter of 1402 in the form of split-plot randomized complete blocks design with three replications in the desert research greenhouse of the Faculty of Desertology of Semnan University. So that the type of cultivation bed as the main factor has three levels (sandy clay soil, clay soil, compost soil) and the sub-factor includes water stress in 4 levels.

The results show in Table 2, and fig 2, 3, 4 and 5. Soil salinity is one of the important characteristics of arid and semi-arid regions in the world. Salinity and water stress affect plant growth and development. Sweet potato (Ipomoea batatas L.) is a crop with economical importance in the world. Sweet potato is an efficient and low production cost crop that is grown during almost the whole year Under stressful conditions, vegetable plants and their response to drought and salinity are mainly based on the type of species, cultivars, and even landraces. It has been studied that Cl − ions are effective for the catabolism of numerous enzymatic and non-enzymatic activities, and these are also known as co-factors for the regulation of the photosynthesis process. This study show that the K uptake decreased by 28 % when the salinity level increased to 14.0 mmol NaCl. K uptake decreases when plants are grown with high salinity levels, which affects yield. Salinity reduces the ability of plants to take up water, and this quickly causes reductions in growth rate, along with a suite of metabolic changes identical to those caused by water stress. The initial reduction in shoot growth is probably due to hormonal signals generated by the roots.

Table 1: Some physical and chemical properties of the experimental field soil

Soil depth (cm)	Texture	FC (vv^{-1})	PWP VV-1	dS Ds(m-1)	CaCo3 %	PH
0-30	Cl	0.55	0.17	0.1	15	6
30-60	Cl	0.66	0.15	0.12	16	6
0-30	L	0.46	0.17	0.13	4	7
30-60	L	0.55	0.19	0.16	2	7
0-30	Com	0.4	0.19	0.12	1.5	7.5
30-60	com	0.5	0.19	0.17	1	7.5

Table 2: Effect of Water stress and salinity on leaf area and Growth traits potato

Salinity (dS/m)	Watering	Cultivar	Dry weight leaves (g)	Leaf area (dm^2)	Dry weight tuber roots (g)	Fresh weight tuber roots (g)
2.00	W1	H	20.95	24.34	87.57	365.3
		U	14.50	20.97	78.50	433.3
	W2	H	14.18	18.31	57.40	234.5
		U	12.65	18.12	56.74	302.0
3.00	W1	H	28.58	31.67	60.88	237.3
		U	11.93	16.25	54.20	299.0
	W2	H	15.55	18.20	64.02	249.8
		U	11.93	16.87	70.91	267.3
3.50	W1	H	19.68	23.73	62.70	243.3
		U	12.73	18.50	85.73	353.7
	W2	H	13.30	16.67	62.43	236.0
		U	8.93	13.14	49.31	267.3

H: 'Huambachero'; U: 'Untacip'; W1: watering each 2 days; W2: watering each 4 days.

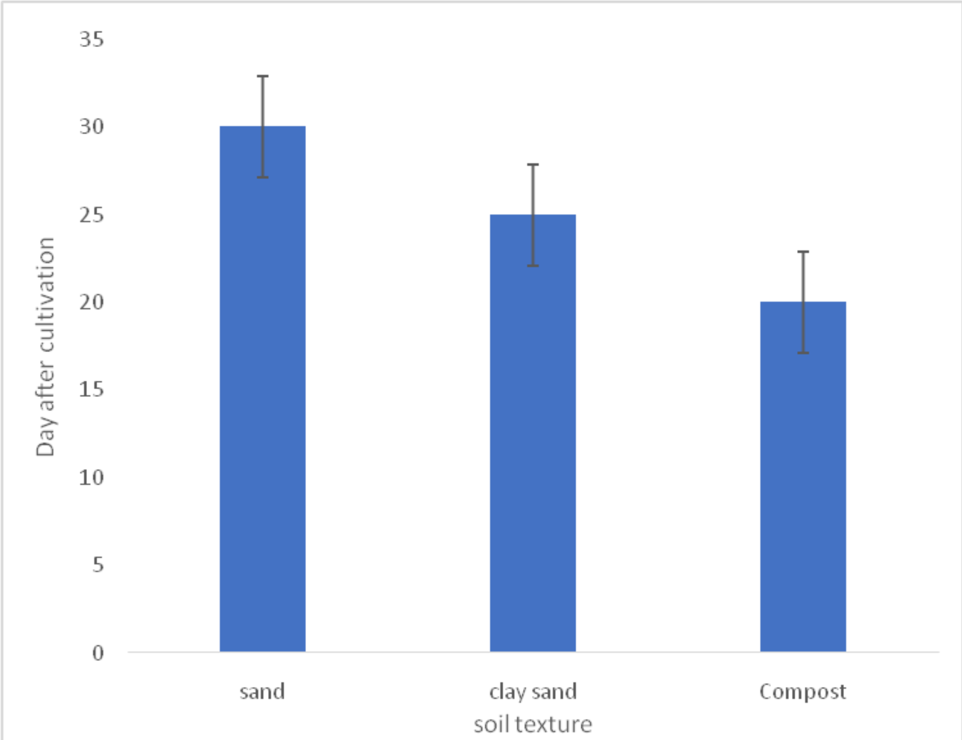

Figure 5: Germination of potato tuber in different soil

The obtained results showed that the length of phenological stages was affected by fertilization and water stress. An increase in animal manure or an increase in irrigation caused acceleration of greening and delay in processing. With the increase of animal manure or the decrease of water, the number of tubers in the plant increased. Tuber weight was not affected by compost, but it increased with increasing planting depth. Tuber performance was affected by compost and water stress. With the increase of compost fertilizer, tuber yield increased and the highest tuber yield (29.01 tons/ha) was obtained from the treatment of 55 tons/ha of fertilizer.

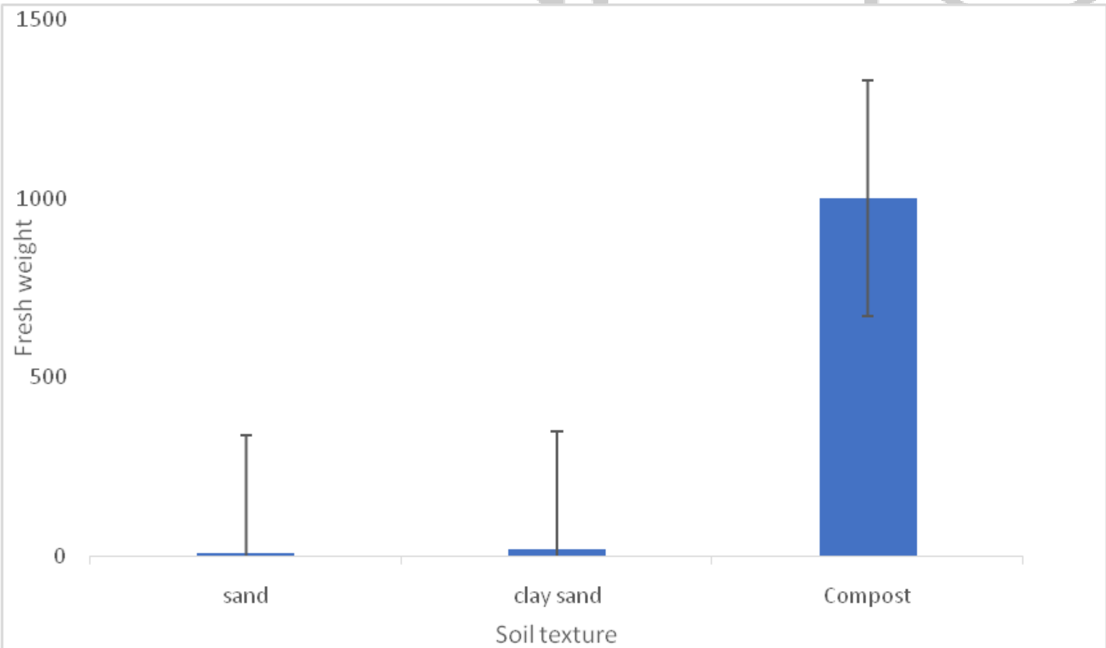

Figure 6: Fresh weight (gr) of aerial part one month after planting potato

Table 3: Analysis variance of the effects of soil texture and water stress on the growth of potato leaf aerial parts

Sources of	Df	ss	Ms	Fs

variation				
Replication	3	2.23	0.7	2.6^{ns}
Soil texture	2	20.8	10	37^{**}
error a	6	1.7	0.2	
main plat	11	24.8		
water stress	3	46	15.3	35^{**}
water stress soil texture interaction	6	242	40.47	92^{**}
error b	27	11	0.4	
subplot	36	399		
total	47	325		

Significant at 1% level *No significant at 5 % level*

Table 4: Analysis variance of the effects of soil texture and water stress on the growth of potato fresh weight roots

Sources of variation	Df	ss	Ms	Fs
Replication	1	2.23	0.7	2.6^{ns}
Soil texture	2	20.8	10	27^{**}
error a	6	1.7	0.2	
main plat	9	24.8		
water stress	3	46	15.3	35^{**}
water stress soil texture interaction	6	242	40.47	90^{**}
error b	27	11	0.4	
subplot	36	399		
total	46	325		

Significant at 1% level *No significant at 5 % level*

Table 5: Analysis variance of the effects of soil texture and water stress on the growth of potato dry weight root.

Sources of variation	Df	ss	Ms	Fs
Replication	1	3.23	0.7	2.9^{ns}
Soil texture	2	30.8	10	47^{**}
error a	6	1.7	0.2	
main plat	9	24.8		
water stress	3	46	15.3	45^{**}
water stress soil texture interaction	6	342	40.47	75^{**}
error b	27	11	0.4	
subplot	36	499		
total	46	325		

Significant at 1% level *No significant at 5 % level*

Table 6: Analysis variance of the effects of soil texture and water stress on the growth of potato fresh weight leaves

Sources of variation	Df	ss	Ms	Fs
Replication	1	2.23	0.6	2.4^{ns}
Soil texture	2	20.8	10	27^{**}
error a	6	1.7	0.2	
main plat	9	24.8		
water stress	3	46	15.3	45^{**}
water stress soil texture interaction	6	242	30.47	88^{**}
error b	27	11	0.4	
subplot	36	400		

total	46	323
Significant at 1% level	*No significant at 5 % level*	

Table7: Analysis variance of the effects of soil texture and water stress on the growth of potato dry weight leaves

Sources of variation	Df	ss	Ms	Fs
Replication	1	6.23	0.6	2.1^{ns}
Soil texture	2	20.8	10	27**
error a	6	1.7	0.2	
main plat	9	24.8		
water stress	3	46	17.3	45**
water stress soil texture interaction	6	240	33.47	80**
error b	27	11	0.7	
subplot	36	800		
total	46	823		
Significant at 1% level	*No significant at 5 % level*			

Potato is a comparatively water-efficient crop that produces more calories per unit of water utilized L water is required to produce a kilogram of potatoes, which is significantly less than other globally most produced crops (rice, wheat, and maize); these require 1408 L, 1159 L, and 710 L of water to produce a kilogram of rice, wheat, and maize, respectively. Despite high water use efficiency, potato is very susceptible to drought stressDurrant et al (1973).

One primary reason is the need for a large amount of irrigated water .Depending upon agroclimatic conditions and soil available water, potato, on average, may require irrigation water between 143 mm to 313 mm. Bodlaender et al. 1964, reported that potatoes need 126–381 mm and 212–226 mm irrigation water to achieve potential potato yield in China and India, respectively. In dryer years—such as 2018 in the United Kingdom—the minimum irrigation water requirement increased to 154 mm. They also reported that during dry years in the United States, potatoes use 10 mm water every 24–36 h after flowering to harvesting, making the total irrigation water requirement up to 610 mm. Compared to potatoes, most other crops in Europe require less irrigation water. The irrigation requirement of sugar beet (0–253 mm), cereals (0–82 mm), carrots (0–258 mm), and strawberries (0–132 mm) are significantly less than potato.

The dry weight of all organs decreased drastically due to different levels of dehydration stress. The lowest dry weight of the organs was produced under very severe stress. The severe and very severe stress caused the plant to reach the maximum dry matter of the stem and root sooner and become shriveled.. due to the decrease in the amount of water, the production of dry weight (biomass) decreased due to the increase in respiration and decrease in carbonization, and as a result, the dry weight Plant organs and photosynthesis levels decreased, and with the increase in water content, the maximum production of dry matter was obtained in less timCampbell (1974, 1976).

In the treatment of severe stress, about minus one megapascal and minus one and a half megapascals, the reduction of dry matter is faster. In very severe stress, because the plants had received enough water until the four-leaf stage, they grew well at first, but because they received very little water after that, the dry matter loss increased.

Table 8. A agro-morphological and physiological traits of potato for the treatment combinations of drought water stress and soil texture.

Soil texture	Drought Stress MPa	PH (cm)	LAI (%)	WSD (%)	RWC (%)	Pn (μmol/m^2/s)	Tr (mg/dm^2 /h)	Ci (ppm)
Sandy	-0.3	85.75 a	3.44a	14.37 a	82.75 a	14.83 a	2.93 a	263.33a
	-0.6	93.37 a	4.03b	12.40 b	84.87 b	11.08 b	3.44 b	268.12b
	-1	95.61 b	3.93 c	10.80 a	86.92 c	10.16 b	3.34 b	272.26c
	-1.5	90.23 c	3.84 d	12.70 b	85.12 b	14.38 c	3.26 b	268.59c
clay	-0.3	77.70a	4.34c	15.01a	90.33a	13.22a	2.90a	290.23a
	-0.6	66.6b	2.03d	13.30b	87.20c	10.11b	4.44b	300.20b
	-1	88.22c	5.03a	16.02c	99.02a	14.02c	3.00c	287.11a
	-1.5	90.40d	4.02a	14.22b	100.02c	17.02d	1.00d	310.00c
Compost	-0.3	90.00a	5.34a	16.01a	87.02ab	12.00a	4.00a	300.00a
	-0.6	77.50c	3.21b	15.02b	91.04b	16.12b	4.34a	230.21b
	-1	97.30b	2.00d	13.23c	88.05c	18.10c	5.00b	300.00c
	-1.5	87.340a	4.02a	16.03b	101.00d	20.00cd	2.00c	220.22d

PH: plant height; LAI: leaf area index; WSD: water saturation deficit; RWC: relative water content; Pn: net photosynthesis rate; Tr: transpiration rate; Ci: intercellular CO2 concentration; Means with similar letters in each column are not significantly different at 0.05 probability level based on least significant difference test.

Results of analysis of variance are shown in Table 9 show that stress and soil texture significantly affected leaf and shoot dry weights, number of tubers, percentage of tuber dry matter, WUE, chlorophyll index and stomatal conductance of the potato plants. Drought stress had significant effect on all agro-morphological and physiological traits of potato, except number of tubers, tuber dry weight, chlorophyll index and stomatal conductance.CaryandWright. (1971)

Plants must decline the stomatal conductance to counteract with negative effects of stress, and as a result, it caused partial closure of the stoma that reduced net photosynthesis rate, transpiration rate, intercellular CO2 concentration and also SPAD (in the first year), which consequently, decreased tuber dry weight, plant height, leaf dry weight, shoot dry weight, number of tubers and number of stolons. However, percentage of tuber dry matter increased with increasing drought stress because amount of moisture in potato tuber reduced with drought stress, which decreased tuber fresh weight relative to tuber dry weight. Stomata are the main locations that are affected by the moisture shortage

4.Discussion

Potato is the third most consumed crop globally after rice and wheat. It is a short-duration crop, versatile in use, suitable for growing in a wide range of environments, and its production is increasing rapidly. The modern potato is considered a drought-sensitive crop, and it is susceptible to yield loss because of drought stress

Consumption potato production in the North-Western European Potato Growers (NEPG) zone is forecast to fall to 21.2 million metric tonnes, a decline of 6.0% year-on-year (y-o-y), based on current yield estimations. This is attributable to a drop in production in Belgium, France and Germany, which offsets the growth in the Netherlands.

Local weather influences led to a huge variation in yields across the NEPG zone. Yields are estimated to decline by 7.8% y-o-y, to 42.1t/ha in the NEPG zone, with the highest drop in Belgium, estimated down 21.3% y-o-y, to 38.9t/ha. Furthermore, yields fell in Belgium, Germany and France, on the back of adverse summer drought conditions, a critical development period for potatoes. Warmer than average temperatures, combined with a lack

of rain, affected the early growth of the potatoes and limited development during bulking before harvestAgeeb (1968).

Potato is a cold-friendly vegetable, except for vegetables.It is a cool season. One of the important factors in growth and performancePotato is the date of cultivation(Potato Council 2009). . Tuber production and quality in potatoUnder the influence of several factors, including moisture stress, weather and so onNutrition is determined[10]The effect of temperature fluctuations on growth andAbnormalities of the glands and their unfavorable quality in a certain areaGeography is related to the climate characteristics of the region and beyondThe power of control is the farmers. But if by adopting the appropriate planting date inEach region can avoid the collision of growth stages with temperature stressIt changed the possible conditions in favor of optimal tuber formation in potato(Epstein. and Grant. 1973).

It is possible to prevent damage to the quality of the production glandsAt the same time, he also improved the production quantityThey stated that due to the delay in plantingOur research has shown that potato, the number of tubers increases, but the average weight of the tubers increasesdecreases)Chapman. and Loomis1953)

In the study of the effect of planting date on indicesPhysiologically, we concluded that leaf area index and speedThe growth of CGR and total dry matter is affected by the cultivation datetakes. The critical period of growth in the potato plant is its nodulation stagewhich is the most sensitive to changes in temperature and photoperiod(photoperiod) that can be harvested by choosing the right planting dateThe above step was prevented by high temperatureResults of composite variance analysis of experimental dataHe said that the effect of planting date and soil texture required time to obtain at least 50%It was significant P ≥0.05. But the effect of water stress and its interactions with soil texture were not significant.The average comparison of the obtained data indicates that inTotal in the date of planting 20 months in the longest possible time50% green crop has been achieved. in historyDecember crops, 20 meaningful differences from the point of view50% green crop did not occur. In this date, plantings inIn the shortest time, 50% green crop was obtainedBoyer (1976, 1970).

5. Conclusions

The effect of water stress on plant morphology, production rate and yield is discussed based on the literature.

Compared to other species the potato is a water stress sensitive plant. The reduction of yield as a result of water stress can be caused by reduced leaf area amount and/or reduced photosynthesis per unit of leaf area. Water shortage during the tuber bulking period decreases yield to a larger extent than drought during other growth stages.

The relation between the stress parameters relative water content (RWC), leaf water potential (LWP) and stomatal diffusion resistance on the one hand and photosynthesis on the other is discussed. Further it is shown how the amount of water needed by the potato crop depends on climate, soil and plant characters. Finally the effect of water stress on yield and varietal differences to shortage of moisture are discussedEpsteinand Grant (1973). Globally, drought represents a limiting factor for potato production and has potential consequences on food security worldwide. This work consists of investigating the impact of water deficit intensity and duration on the physiological activity of potato plants at two specific development stages. Accordingly, we inflicted water stress treatments consisting of the application of −40 (dry) and −60 kPa (very dry) of soil matric potential across three stress periods of 1 (1D), 3 (3D), and 7 (7D) days.

6. Acknowledgment.

We thanks Dr. Mohamad kiakianian and Nahid Ara from collaboration laboratory assistant in this research.

7. Reference

Ackerson, R.C., D.R. Krieg, T.D. Miller and R.G. Stevens. 1977. Water relations and physiological activity of potatoes. J Am Soc Hortic Sci 102:572–575.

Ageeb, D.A. 1968. The basis for the different responses to drought of Majestic and King Edward potatoes. Ph.D. Thesis, Univ of Nottingham. (As cited by Harris (25)).

Barrs, H.D. 1968. Determination of water deficits in plant tissues. In. Water deficits and plant growth, pp 236–368. Ed. T.T. Kozlowski. Academic Press, New York.

Boyer, J.S. 1970. Differing sensitivity of photosynthesis to low leaf water potentials in corn and soybean. Plant Physiol 46:236–239.

Boyer, J.S. 1976. Water deficits and photosynthesis. In. Water deficits and plant growth. Vol IV. pp 154–190. Ed. T.T. Kozlowski. Academic Press, New York.

Campbell, G.S. and R. Kunkel. 1974. When to irrigate. p. 63–70. Proc 13th Ann Wash State Potato Conf & Trade Fair, Moses Lake.

Campbell, M.D., G.S. Campbell, R. Kunkel and R.J. Papendick. 1976. A model describing soil-plant-water relations for potatoes. Am Potato J 53:431–441.

Cary, J.W. and J.L. Wright. 1971. Response of plant water potential to the irrigated environment of southern Idaho. Agron J 63:691–695.

Cavagnaro, J.B., B.R. de Lis and R.M. Tizio. 1971. Drought hardening of the potato plant as an after-effect of soil drought conditions at planting. Potato Res 14:181–192.

Chapman, H.W. and W.E. Loomis. 1953. Photosynthesis in the potato under field conditions. Plant Physiol 28:703–716.

Corey, A.T. and G.R. Blake. 1953. Moisture available to various crops in some New Jersey soils. Soil Sci Soc Am Proc 17:314–317.

Davies, W.J. 1977. Stomatal responses to water stress and light in plants grown in controlled environments and in the field. Crop Science 17:735–740.

Durrant, M.J., B.J.G. Love, A.B. Messeen and A.P. Draycot. 1973. Growth of crop roots in relation to soil moisture extraction. Ann Appl Biol 74:387–394.
Epstein, E. and W.J. Grant. 1973. Water stress relations of the potato plant under field conditions. Agron J 65:400–404.