Turkish Journal of FIELD CROPS

*Turk J
Field Crops
2024, 29(2), 177-189
DOI: 10.17557/tjfc.1386899*

EFFECT OF WATER STRESS ON YIELD AND YIELD COMPONENTS OF PEANUT CULTIVARS

Mohammadreza HADDADI, Ebrahim AMIRI, Majid ASHOURI, Seyyed Mostafah SADEGHI, Naser MOHAMMADIYAN ROSHAN*

Department of Water Engineering, Lahijan Branch, Islamic Azad University, Lahijan, Iran
**Corresponding author: eamiri57@yahoo.com*

Received: 06.11.2023

ABSTRACT

To evaluate the effect of irrigation regimes on yield and water productivity, a split plot experiment was conducted with three replications in Iran in 2017 and 2018. The main treatment consisted of 40%, 60%, 80% and 100% water requirements, respectively, and the sub-treatment consisted of four peanut cultivars which are types of peanuts that are cultivated in Iran market (Guil, Gorgani, Jonobi and Mesri). Each 100 grams of these introduced peanuts contains 25.5 grams of protein and 48.4 grams of fat. Seed yield in 2017 with an average of 1316 kg ha^{-1} was higher than seed yield in 2018 with an average of 1022 kg ha^{-1} Due to irrigation, seed yield in the treatments of 40% and 60% of water requirement with the average of 1345kg ha^{-1} and 1379 kg ha^{-1}, respectively, had the highest value. Due to the year of irrigation, the maximum seed yield in 2017 and in treatments of 40% and 60% of water requirement were with an average of 1494 kg ha^{-1} and 1593 kg ha^{-1}, respectively. In peanut cultivars, Jonobi cultivar with an average of 1273 kg ha^{-1}, had the highest value compared to other cultivars. Due to irrigation×cultivars, 40% water requirement treatment and Jonobi cultivar with an average of 1732 kg ha^{-1}, and also 60% water requirement treatment and Guil cultivar with an average of 1667 kg ha^{-1} had the highest value. The maximum seed yield due in year ×irrigation ×cultivar was in 2017, and in the treatment of 40% of water requirement and in the Jonobi cultivar with an average of 1856 kg ha^{-1}. Water productivity on biological yield (4.32 kg m^{-3}) and pod yield (1.96 kg m^{-3}) in Mesri cultivar and Water productivity on seed yield in Gorgani cultivar were 0.54 kg m^{-3}.

Keywords: Cultivar, Irrigation, Peanut, Stress, Water Productivity.

INTRODUCTION

Peanut is one the oil crops in the world that is cultivated on a large scale for producing oil and nut consumption in many countries of the world, such as Iran. Peanut is the third major oilseed crop in the world next to soybean and cotton (Nayak et al., 2019). Peanuts are native plants of Brazil and have found their way from Brazil to other parts of the world (Abdzad Gohari, 2018). Peanut seeds contain about 25% to 30% protein which has the amino acids of tryptophan, lysine, methionine and cysteine (Amiri et al., 2015; Hammons et al., 2016; Virk et al., 2019). Produced peanut butter is available in many small shops, and small packets of roasted peanuts are commonly sold by street vendors (Fulmer et al., 2020). However, drought which is the single most devastating environmental stress, not only decreases crop productivity (Lambers et al., 2008). It has become increasingly apparent that crop maturity in seed peanut should be a priority for the peanut industry (Pierre et al., 2019). One of the most important economic sectors in Iran is the agricultural sector, and in the meantime water is the most important factor limiting agricultural production. In this regard, deficit irrigation is an optimal strategy to cultivate crops under water scarcity conditions which is accompanied by reduced crop yield. Peanuts exhibit drought resistance primarily due to their ability to maintain a functional root system under water stress. Water stress encourages peanut roots to grow deeper into the soil, allowing them to extract water from depths of at least 180 cm in fine sandy soils (Lenka and Mishra, 1973; Allen et al., 1976; Narasimham et al., 1977). When peanut cultivars experience soil moisture stress during the early vegetative stage, individual seed weight increases. However, water stress during the pod initiation and development stages reduces the suitability of seeds for planting (Nautiyal et al., 1991). Imposing water deficits during the vegetative phase results in higher final yields, improved water use efficiency, and increased dry matter production, including economic yield (Ong, 1984; Nautiyal et al., 2000). The main objective of deficit irrigation is to increase water productivity by reducing the amount of irrigation water at each turn or elimination of irrigation methods which have the least efficiency. Deficit irrigation can be also utilized for expanding the cultivation level and maximizing or stabilizing the production of a region's crops. Some of the advantages of deficit irrigation include reducing production costs, reducing irrigation water costs and increasing application efficiency of the irrigation water (Giret and Rize, 2009). Adjusting the timing and amount of deficit irrigation throughout the growing season at various growth stages can potentially increase peanut yield by altering the distribution of dry matter between vegetative and reproductive organs (Ong,1984). peanuts require adequate water throughout all stages of physiological development to achieve optimal productivity (Rao et al., 1988; Meisner and Karnok, 1992), certain stages, particularly flowering and pod filling, are more sensitive to soil moisture levels compared to early vegetative or late maturity stages (Doorenbos and Kassam, 1979; Howell et al., 1980). Insufficient water during these critical stages can significantly reduce kernel yield and prevent the efficient use of available water (Pallas et al., 1979; Ike, 1986; Boote and Ketring, 1990).Water deficit significantly reduces yield potential of peanut worldwide. Availability of drought tolerant cultivars is essential, but their selection is difficult, in particular in environments where rainfall is unpredictable (Balota., 2020). Soil moisture retention is important for peanut production as well as water conservation in irrigated and non-irrigated fields (Hawkins et al., 2016). The results of Abdzad Gohari and Amiri (2018) study on peanuts indicated that deficit irrigation is good for the plant due to water conservation and increased water use efficiency, however, while extreme deficit irrigation results in a lot of water saving, it also decreases yield. One of the basic management methods of agriculture is providing conditions to maximize the crop production relative to the consumed water (Shinde and Laware, 2010). Water efficiency and productivity are indices of optimizing the consumption of water (Kijene et al., 2003). This concept is widely used in order to recognize and provide the yield ratio as biological yield or economic yield per unit volume of water consumed. Obtaining the optimum size of production function and its implications will be very beneficial for crop production and the future economic activity of farmers and also for maintaining and strengthening the status of agricultural products in the domestic and international consumption markets. The production function is a mathematical equation between product yield and consumption inputs in the production process. The general form of the production function can be written as equation (1):

$$Y = F(X_1, X_2, \ldots, X_n) \qquad \text{Equation (1)}$$

This equation shows that the product value (Y) can be calculated in different ways through multiple values of the production factors (X_i). Estimation of production function also makes it possible to separately identify the role and importance of each of the production inputs (Geerts and Raes, 2009). One of the applications of production functions is determining the optimal irrigation value (Bontang et al., 2010). Kijne et al., (2003) achieved a quadratic production function. In a study, Abdzad Gohari et al. (2018) examined the amount of water consumed and the amount of nitrogen on peanuts and they obtained quadratic nonlinear production functions. The purpose of the present study was to evaluate the performance and efficiency of water use on peanut cultivars with deficit irrigation and full irrigation conditions.

MATERIALS AND METHODS

For the examination of yield and water productivity in peanut cultivars, Randomized Complete Block Design (RCBD) arranged in Split Plots in replications in Guilan province (in Iran) with latitude of 37°16', and a longitude of 49°56', which is averagely -5 meters above sea level. This test was carried out in 2017 and 2018. The main treatments included irrigation with 40%, 60%, 80% and 100% water requirements for irrigation management, and the sub-treatment included four peanut cultivars (Guil, Gorgani, Jonobi and Mesri). The meteorological parameters are presented in Table 1. In order to determine physicochemical properties of soil, the farm soil was randomly sampled at different depths of 0-30 cm and 30-60 cm, prior to preparing the soil and applying the fertilizer. The soil type of the area was loam. The other properties of the soil in the regions are presented in Table 2. The field was plowed in april, and it was turned flat and soft by using a rotary. After that the seeds were sown in soil. Peanut seed emergence occurs between 6 to 11 d after planting, depending upon soil and air temperatures (Canavar and Kaynak, 2010). As a general rule, peanut germination is considered optimum in the soil temperature range of 20℃ to 35℃ at a 10 cm soil depth for three consecutive d and air temperatures between 27℃ and 32℃ are considered optimum for peanut growth and yield (Kvien et al., 2019; Virk et al., 2019). The amount of water that would be consumed during the growth period was provided through irrigation water and rainfall. In order to determine irrigation treatment, soil moisture depletion method was used and the amount of required water of the plant was considered as 100% irrigation treatment. Other irrigation treatments were considered as a percentage of this amount. To achieve the treatment of 100% irrigation, soil moisture at the root of the plant was calculated by Equation (2) in way to that the soil moisture up to the height of the root can reach the capacity value of the farm. The duration of irrigation depends on the time that the moisture reaches the root of the plant after starting the irrigation (Abdzad Gohari et al., 2018).

$$d_n = (\theta_{Fc} - \theta_i).\rho_b.D_r \qquad \text{Equation (2)}$$

Ú$_{Fc}$: water content weight percentage at field capacity. Ú$_i$: water content weight percentage in soil. ρ_b: Soil bulk density (Grams per cubic centimeter). D_r: Effective root height (cm). To measure biological function of seed and pods in each plot, 12 plants were randomly selected after removal of two rows of cultivars from each side. Then the pods, leaves and stems were separated from the plant and placed in the oven at 70°C for 48 hours. The samples were weighed by scales (one-hundredth of a gram precision) after they were dried, and then the seeds were separated from the pods and converted to kg ha^{-1} unit. The amount of water productivity was obtained by dividing the yield (kg ha^{-1}) by the total amount of water used (Cubic meters per hectare). The amount of irrigation water and the water used can be seen in Table 3. For data analysis, MSTATC software was used to analyze the variance and mean comparison (Duncan at 5% probability level). Excel software was used for drawing the charts and the value of production functions was determined by using STATISTICA V5.5A model.

Table 1. Meteorological average of the study area in 2017 and 2018.

	Jun	Jul	August	September
Precipitation (mm)	27.4	41.3	65.6	21.8
Average Relative Humidity (%)	58.9	62	57.2	64.5
Wind speed (ms^{-1})	2.6	3.3	2.7	2.5
Maximum temperature (°C)	28.1	29	30.8	28.6
Minimum Temperature (°C)	19.3	21	22	19.4

Table 2. Characteristics of soil in the study area

	Particle size distribution %							
Soil depths (cm)	Sand	Silt	Clay	Organic Carbon	EC (%)	Total Nitrogen (%)	Total Phosphor (mg kg^{-1})	Total Potassium (mg kg^{-1})
0-30	47	32	21	0.65	0.646	0.03	3.17	181
30-60	49	31	20	0.66	0.632	0.03	2.33	150

Table 3. The amount of water use and the amount of irrigation in 2017 and 2018.

Irrigation management	Year	Amount of irrigation (mm)	Water use (mm)
40% water requirement	2017	150.9	349.6
	2018	118.4	232.8
60%water requirement	2017	154.1	352.8
	2018	158.8	272.9
80%water requirement	2017	271.7	470.4
	2018	249.4	363.8
100% water requirement	2017	389.2	587.9
	2018	340.4	454.8

RESULTS AND DISCUSSION

Biological yield

Effect of cultivars, effect of year × cultivars, effect of irrigation×cultivars and effect of "year × irrigation × cultivars" were significant at ($p<0.01$) n biological yield (Table 4). Jonobi cultivar with the mean of 9396 kg ha^{-1} had highest biological yield among all other cultivars (Figure 3). The highest biological yield was obtained for the mutual effect of year×cultivar for Jonobi cultivar in 2017 with a mean of 10075 kg ha^{-1} (Figure 4). Regarding the mutual effect between irrigation and cultivars, the maximum biological yield was obtained in 80% water requirement in Guil cultivar with a mean of 10880 kg ha^{-1} (Figure 5). Maximum biological yield was seen for the mutual effect of year×irrigation×cultivars in 2017 in the treatment with 100% water requirement and in the Jonobi cultivar with a mean of 12170 kg ha^{-1} (Table 11). By increasing vegetative growth duration and the effective life of the canopy, active photosynthetic absorption increases and it leads to increased dry weight of aerial organs (Anjam et al., 2011). Drought causes a reduction in the absorption of minerals and nutrients and this can also reduce the growth of aerial organs of the plant. Dry weight of aerial organs is greatly reduced under drought stress and eventually biological yield will also decrease. Because water stress eventually reduces carbon dioxide intake through closing the pores, and in this way, it results in a significant decrease in dry matter production by affecting metabolic activities (Anjam et al., 2011).

Pod yield

Effect of cultivars, effect of "year × cultivars", effect of irrigation×cultivars and effect of "year × irrigation × cultivars" were significant at ($p<0.01$) level on pod yield (Table 4). For the mutual effect of irrigation×cultivars, maximum pod yield was obtained in the treatment with 100% water requirement and in the Jonobi cultivar with a mean of 4513 kg ha^{-1}, and also in the treatment with 80% water requirement it was obtained in Guil cultivar with a mean of 4502 kg ha^{-1} (Figure 5). Maximum pod yield was seen for the mutual effect of year×irrigation×cultivars in 2017 in the treatment with 100% water requirement and in the Jonobi cultivar with a mean of 5230 kg ha^{-1} (Table 11).

In early stages of growth of pods, severe drought stress reduces their growth rate and leads to a significant reduction in the total number of pods (Liu et al., 2003; Anjam et al., 2011). In a study by Abdzad Gohari et al. (2011), It has been demonstrated that moisture is a crucial factor in the development of peanuts, and a lack of moisture during the pod growth phase can ultimately lead to a reduced pod yield. Shinde and Laware (2010) in their study showed that moisture deficiency at flowering time reduces peanut yield.

Table 4. Mean squares form the combined ANOVA for Agronomic Traits.

Source	df	Biomass yield	Pod yield	Seed yield	100-seed weight	Number of pods per plant
Year	1	22046458.59^{ns}	31711747.01^{ns}	2073288.17^{ns}	2734.93^{ns}	840.17^{ns}
Replication	4	9215010.25^{ns}	1329035. 63^{ns}	517149.79**	1027.27**	137.42^{ns}
Irrigation	3	17829265.45^{ns}	2397237. 53^{ns}	1210092. 40**	4024.67**	138.47^{ns}
Year×Irrigation	3	9118835.45^{ns}	188883.69^{ns}	77851.31**	510.13^{ns}	185.36^{ns}
Error	12	7741850.74	1605332.43	83893.71	169.32	84.92
Cultivar	3	5560716.04**	1005525.47**	196347. 07**	175.22**	88.36**
Year×Cultivar	3	3740454.04**	698157. 81**	64550.19^{ns}	103.46**	69.69**
Irrigation×Cltivar	9	6514854.16**	1027251. 33**	433553.99**	779.6**	43.15**
Year×Cultivar×Irr	9	4161357.38**	875999.32**	218508.85**	367.04**	42.93**
Error	48	252144.79	42778. 78	8424.70	15.22	4.514
CV (%)		5.75	5.48	7.85	6.07	7.47

ns = non-significant; * and ** = Significant at 5% and 1% probability level, respectively.

Seed Yield

Effect of year, effect of irrigation, effect of year×irrigation, effect of cultivars, effect of year×cultivars, effect of irrigation×cultivars and effect of year×irrigation×cultivars were significant at (p<0.01) on seed yield (Table 4). In irrigation management, seed yield with the treatment with 100% and 80% water requirements, had the highest value with the means of 1345 kg ha^{-1} and 1379 kg ha^{-1} respectively (Figure 1). In the effect of year×irrigation, maximum seed yield was in 2017, with the treatment with 100% and 80% water requirements with the means of 1494 kg ha^{-1} and 1593 kg ha^{-1}, respectively (Figure 2). In peanut cultivars, Jonobi cultivar had the highest value with a mean of 1273 kg ha^{-1} (Figure 3). For the effect of irrigation×cultivars, the highest values were obtained in the treatment with 100% water requirement in Jonobi cultivar with a mean of f 1732 kg ha^{-1}, and also in the treatment with 60% water requirement in Guil cultivar with a mean of 1667 kg ha^{-1} (Figure 5). The maximum seed yield for effect of year×irrigation×cultivars was observed in 2017 in the treatment with 100% water requirement in the Jonobi cultivar with a mean of 1856 kg ha^{-1} (Table 11). Water stress causes an extreme reduction in the yield (Bunari et al., 1992; Bontang et al., 2010). Amiri et al., (2010) in their study reported the maximum seed yield for peanuts with a condition of 100% water requirement. Abdzad Gohari et al., (2018) examined different peanut cultivars under water stress conditions and non-stress conditions. They concluded that seed yield was higher in all cultivars in non-stress conditions compared to conditions with water stress. Bontang et al (2010) examined the effect of intervals irrigation with periods of daily, two days and three days. They concluded that the maximum seed yield was achieved with daily irrigation conditions.

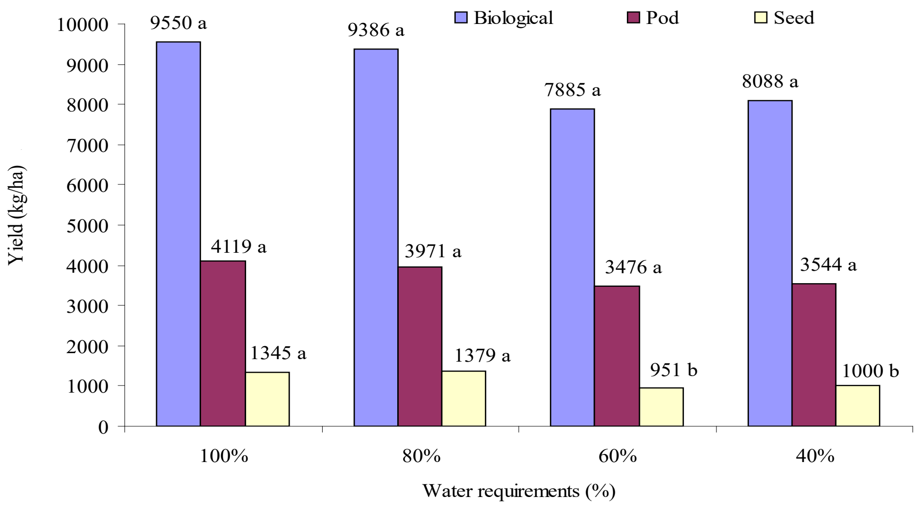


Figure 1. Effect of irrigation management on biological, pod and seed yield in peanut.

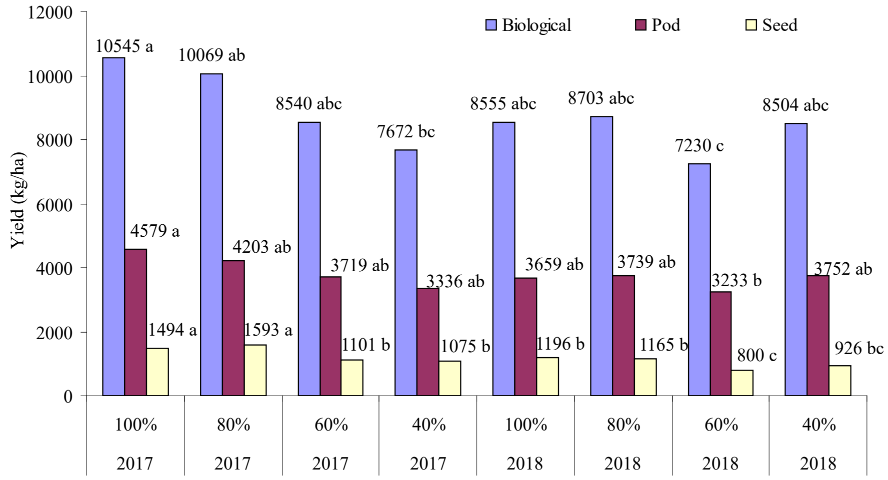


Figure 2. Effect of irrigation×year on biological, pod and seed yield in peanut.

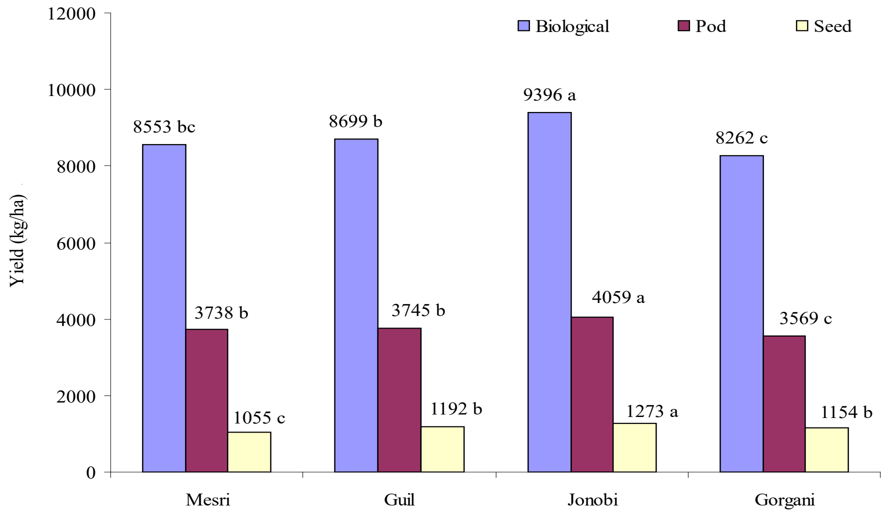


Figure 3. Biological, pod and seed yield in different peanut cultivars.

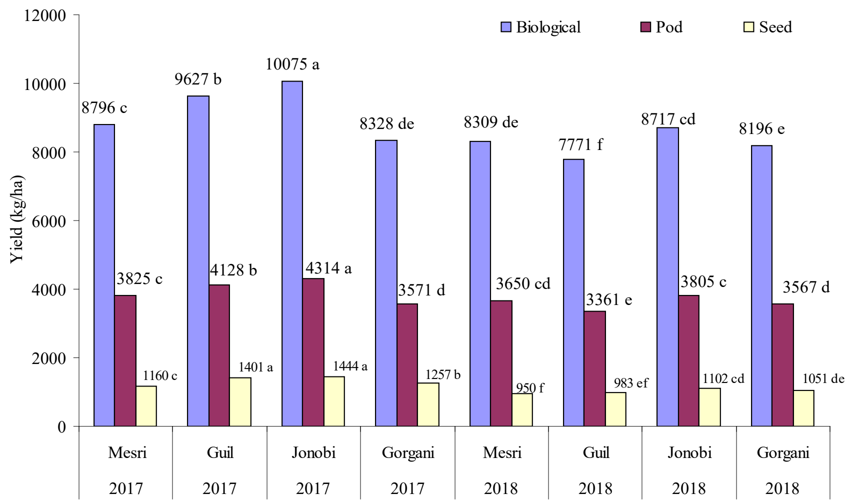


Figure 4. Effect of year×cultivars on biological, pod and seed yield in peanut.

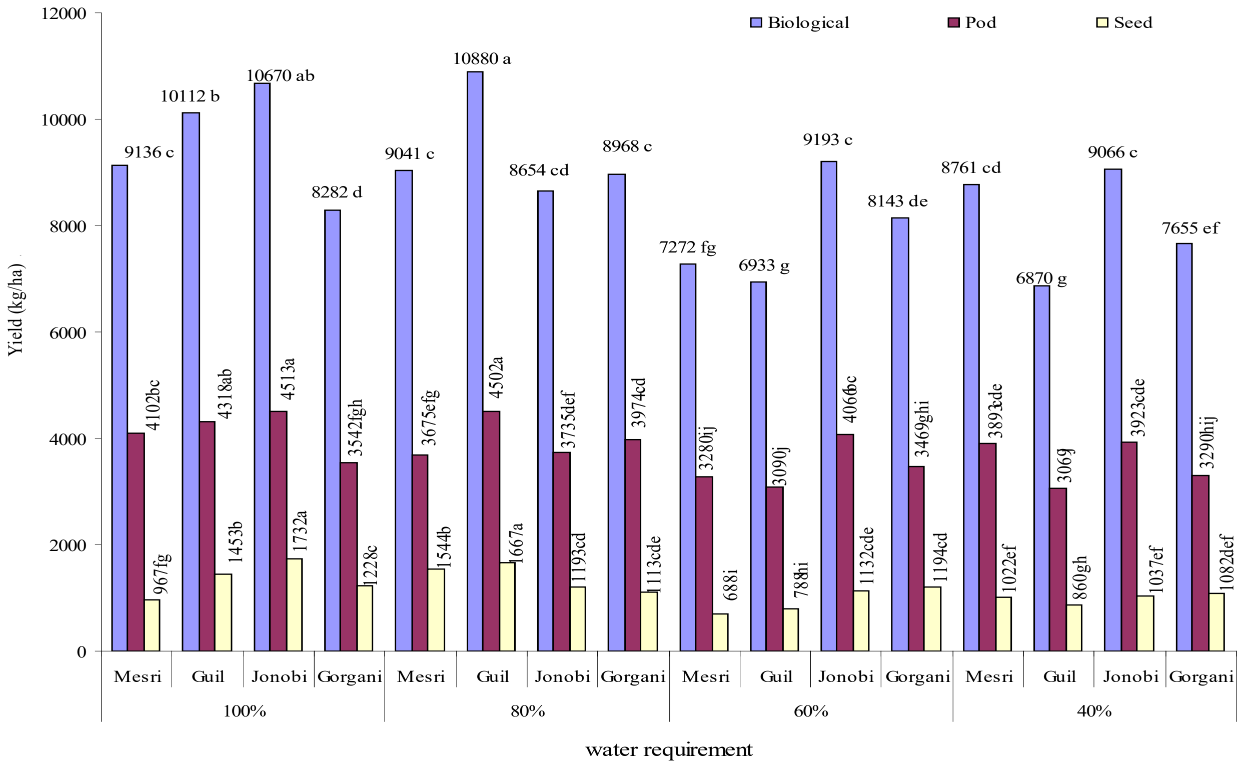


Figure 5. Effect of irrigation×cultivars on biological, pod and seed yield in peanut.

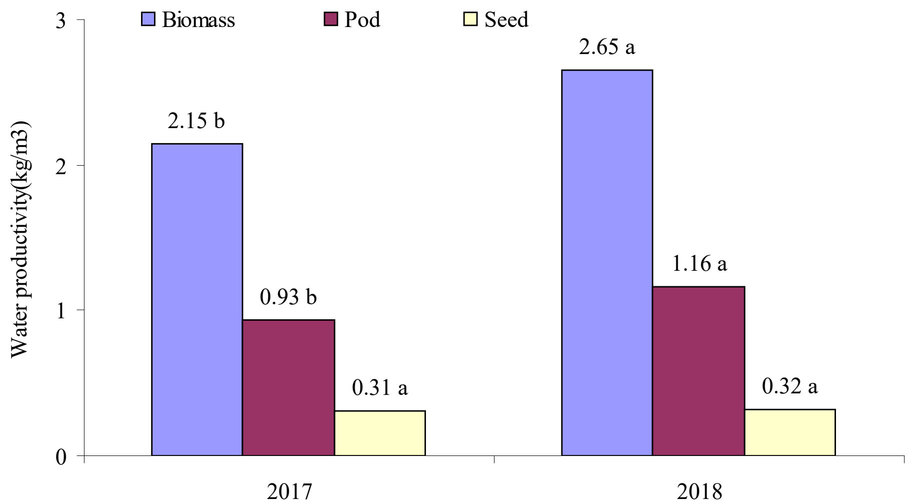


Figure 6. Water productivity in biomass, pod and seed yields in the studied years.

100-seed weight

The effects of year, irrigation, cultivars, irrigation × cultivars and year × irrigation × cultivars on 100-seeds weight were significant at ($p<0.01$) (Table 4). The 100-seeds weight was higher in the first and the second years with 69.6 g and 58.9 g, respectively (Table 6). Higher average of 100-seeds weight was related to 100% and 80% of the water requirements; i.e. 72.8 g and 77.9 g, respectively (Table 7). Compared to other cultivars, the 100-seeds weight in the Jonobi cultivar with an average of 66.9 g and the Gorgani cultivar with an average of 66.1 g had the highest value (Table 8). The highest effect of "year × cultivar" as found in Jonobi , Gorgani and Mesri cultivars (70.4 g , 71.8 g and 72.5 g respectively) in the first year, compared to the second year (Table 9). The highest effect of irrigation×cultivars was related to the 80% of water requirement and Mesri and Guil cultivars with an average of 90.4 g and 89 g, respectively (Table 10). For the effect of year×irrigation×cultivars the maximum amount of 100-seeds weight was observed in the 60% of water requirement and in Mesri cultivar with an average of 96 g in the first year (Table 11). Kabadagi and Setty (2010) evaluated of peanut cultivars and observed that the 100-seeds weight under stress conditions was lower than stress-free conditions. Shinde and Laware (2010) showed that water stress reduces 100-seeds weight. At the seed filling stage, drought stress affects 100-seeds weight either by reducing the movement of storage materials toward the seed due to water restriction, or by reducing the share of photosynthesis in leaves. For this reason, decreasing the movement of storage materials and water restriction because of drought led to the limited translocation of nutrients in the plant and reduction in 100-seeds weight.

Number of pods per plant

The effects of the peanut cultivars, year×cultivar, irrigation×cultivars and year×irrigation× cultivars on the number of pods per plants were significant (p<0.01) (Table 4). The highest number of pods per plant was in Jonobi cultivar with an average of 31 pods (Table6). For the effect of year×cultivar, maximum number of pods per plants was observed in Jonobi cultivar with an average of 34 pods in the first year (Table 9). About the effect of irrigation×cultivars, maximum number of pods per plants was obtained in 100% of water requirement and in Jonobi cultivar with an average of 35 pods (Table 10). For the effect of year×irrigation×cultivars, maximum number of pods per plants was observed in the first year for 100% of water requirement and in Guil and Jonobi cultivars with an average of 40 and 43 pods, respectively (Table 11). As the amount of irrigation water increases, the period of pods growth and maturation become longer and the speed of leaves aging becomes slower; then, the number of seeds per plant will increase. On the other hand, reducing the amount of water irrigation and also increasing the temperature, lead to premature aging of the plant.

Pod length

The effects of irrigation, cultivars, year×cultivar, irrigation×cultivars and year×irrigation×cultivars on pods length were significant (p<0.01) (Table 5). For the irrigation effect, the maximum pods lengths were observed in the 100% and 80% water requirements with an average of 4.4 cm and 4.9 cm, respectively (Table 7). Among the peanut cultivars, the maximum amount of pods length was related to Mesri cultivar with an average of 4.3 cm (Table 8). About the interaction effect of year×cultivar, the maximum pods length was observed for Mesri cultivar with an average of 4.6 cm in the first year (Table 9). For the interaction effect of irrigation×cultivars, the maximum length was found in 80% of the water requirements and in Mesri cultivar with an average of 5.3 cm (Table 10). For the effect of year×irrigation×cultivars the maximum pods length was observed in 60% of the water requirement and in Mesri cultivar with an average of 5.5 cm in the first year (Table 11). To achieve the best growth and maximum pods length and yield, the amount of water should not lead to drought stress nor to the accumulation of large amounts of water around the plant's roots; by deviating from this amount of water, it is necessary to determine the exact amount of yield decrease.

Table 5. Mean squares form the combined ANOVA for Agronomic Traits.

Source	df	Pod Length	Number of seeds per plant	Water productivity based on		
				Biomass	Pod	Seed
Year	1	0.375^{ns}	2330.51^{*}	5.861^{*}	1.290^{*}	0.005^{ns}
Replication	4	1.458^{ns}	538.23^{ns}	0.740^{**}	0.106^{ns}	0.039^{ns}
Irrigation	3	10.92^{**}	1240.96^{*}	4.889^{**}	1.044^{**}	0.039^{*}
Year×Irrigation	3	0.247^{ns}	291.54^{ns}	2.515^{*}	0.499^{*}	0.017^{*}
Error	12	1.073	280.174	0.700	0.142	0.009
Cultivar	3	0.792^{**}	462.43^{**}	0.470^{**}	0.092^{**}	0.013^{**}
Year×cultivar	3	1.664^{**}	191.51^{**}	0.432^{ns}	0.081^{**}	0.012^{**}
Irrigation×cultivar	9	0.448^{**}	180.62^{**}	0.676^{**}	0.112^{**}	0.033^{**}
Year×cultivar×Irr	9	0.437^{**}	97.98^{**}	0.558^{**}	0.114^{**}	0.024^{**}
Error	48	0.65	5.771	0.920	0.004	0.001
CV (%)		6.22	4.46	5.93	5.68	8.10

ns = non-significant; * and ** = Significant at 5% and 1% probability level, respectively.

Table 6. Effect of year on agronomic traits

Year	100-seed weight	Number of pods per plant	Pod Length	Number of seeds per plant
2017	69.6 a	31 a	4.0 a	59 a
2018	58.9 b	26 b	4.1 a	49 b

Table 7. Effect of water requirement on agronomic traits

WR	100-seed weight	Number of pods per plant	Pod Length	Number of seeds per plant
100%	72.8 a	31	4.4 a	60 a
80%	77.9 a	30	4.9 a	60 a
60%	53.1 b	27	3.6 b	47 b
40%	53.3 b	26	3.4 b	48 b

Table 8. Traits measured in different cultivars

Cultivar	100-seed weight	Number of pods per plant	Pod Length	Number of seeds per plant
Guil	61.2 b	27 b	4.3 a	52 b
Gorgani	66.9 a	27 b	4.0 b	52 b
Jonobi	62.9 b	31 a	3.9 c	60 a
Mesri	66.1 a	28 a	4.1 b	51 b

Number of seeds per plant

The effects of year, irrigation, peanut cultivars, year × cultivars, irrigation × cultivars and year×irrigation×cultivars on the number of seeds per plant were significant ($p<0.01$) (Table 4). For irrigation effect, the highest number of seeds per plant (average of 60 seeds) was related to 100% and 80% of water requirements (Table 7). Among the peanut cultivars, the highest number of seeds per plant was observed in the Jonobi cultivar with an average of 60 seeds (Table 7) for the interaction of year×cultivar, (Table 7). the maximum number of seeds per plant was found in the Jonobi cultivar in the first year (Table 9). For the interaction effect of irrigation×cultivars, the maximum number of seeds per plant was obtained in 100% of water requirements and in Jonobi cultivar with an average of 71 seeds (Table 10). About the effect of year × irrigation×cultivars the maximum number of seeds per plant was observed in 40% of the water requirement and in Jonobi cultivar with an average of 77 seeds in the first year (Table 11). At the beginning of flowering, the plant grows rapidly; by providing the available moisture, the length of the reproductive period and also the rate of photosynthesis increase. In this situation, more flowers are formed in the plant, which in turn affects the formation of fertile pods and seed production. The reason for decreasing the number of seeds under drought stress is the decline in pods number in the main and secondary brunches. During the flowering stage, supplemental irrigation increases the number of seeds per plant. Plants that were exposed to drought stress during pod formation and growth produced the least number of pods, seeds, and dry matter, compared to plants that experienced drought stress during other growth stages.

Table 9. The effect of different years and cultivars on the measured traits

Year	Cultivar	100-seed weight	Number of pods per plant	Pod Length	Number of seeds per plant
2017	Guil	63.8 b	30 c	4.6 a	57 c
	Gorgani	71.8 a	32 b	3.8 de	60 b
	Jonobi	70.4 a	34 a	3.6 e	64 a
	Mesri	72.5 a	28 d	4.1 bc	53 d
2018	Guil	58.5 de	25 e	4.0 cd	46 f
	Gorgani	62.1 bc	22 f	4.2 b	43 g
	Jonobi	55.5 e	28 d	4.1 bc	57 c
	Mesri	59.6 cd	27 d	4.0 bc	49 e

Table 10. Interaction of water requirements and different cultivars in measured traits

Year	Cultivar	100-seed weight	Number of pods per plant	Pod Length	Number of seeds per plant
100%	Guil	55.4 ef	30 bcd	4.8 b	58 d
	Gorgani	77.0 b	33 ab	4.0 d	61 c
	Jonobi	80.3 b	35 a	4.1 d	71 a
	Mesri	78.6 b	27 efg	4.6 bc	50 f
80%	Guil	90.4 a	28 def	5.3 a	58 d
	Gorgani	89.0 a	31 bcd	4.9 b	64 b
	Jonobi	69.3 c	29 cde	4.8 b	59 b
	Mesri	62.9 d	32 bc	4.4 c	60 cd
60%	Guil	44.7 h	25 fg	3.7 e	42 g
	Gorgani	50.0 g	25 fg	3.5 efg	41 g
	Jonobi	52.1 fg	32 ab	3.4 fg	57 d
	Mesri	65.7 cd	26 fg	3.8 de	48 f
40%	Guil	54.2 efg	27 efg	3.3 fg	48 f
	Gorgani	51.9 fg	22 h	3.6 ef	41 g
	Jonobi	50.1 g	29 de	3.2 g	54 e
	Mesri	57.2 e	26 fg	3.5 efg	48 f

Table 11. Effect of year× water requirements×cultivars on agronomic traits measured in 2017 and 2018

Year	water requirements	Cultivars	Yield (kg ha^{-1})			100-seed weight	Number of pods per plant	Pod Length	Number of seeds per plant
			Biomass	Pod	Seed				
2017	100%	Mesri	9696 def	4405 cd	977 klmn	48 jkl	35 b	5.1 b	68 bcd
		Guil	11310 b	4904 ab	1592 bcde	74.7 ef	40 a	3.6 g-m	70 b
		Jonobi	12170 a	5230 a	1856 a	80.0 de	43 a	3.4 k-o	77 a
		Gorgani	9004 efg	3779 gh	1551 cde	88.6 bc	31 c-f	4.7 bcd	58 fgh
	80%	Mesri	9679 def	3939 efg	1645 bc	96.0 a	31 c-f	5.5 a	62 ef
		Guil	10650 bc	4317 de	1755 ab	93.0 ab	32 b-e	4.8 bcd	69 bc
		Jonobi	9986 cd	4266 def	1488 cde	86.2 cd	34 bcd	4.8 bcd	63 de
		Gorgani	9961 cd	4292 def	1483 cde	81.4 de	35 b	4.5 de	65 cde
	60%	Mesri	8348 g-j	3738 gh	806 no	43.5 lm	30 def	4.0 fgh	54 hi
		Guil	8554 gh	3757 gh	1081 ijk	57.5 hi	30 def	3.0 op	52 ij
		Jonobi	9761 cde	4215 def	1422 efg	61.8 gh	34 bc	3.1 nop	64 de
		Gorgani	7498 jkl	3165 jkl	1096 ijk	67.9 g	24 ijk	4.1 efg	45 lm
	40%	Mesri	7461 jkl	3218 jk	1214 hi	67.9 g	25 hij	3.9 ghij	47 kl
		Guil	7997 h-k	3534 g-j	1175 hij	61.8 gh	27 f-i	3.7 g-l	50 ijk
		Jonobi	8380 g-j	3544 g-j	1010 j-m	53.5 ij	26 g-j	3.2 l-p	50 ijk
		Gorgani	6850 lm	3046 kl	9001 mno	52.2 ijk	24 ijk	3.2 m-p	45 lm
2018	100%	Mesri	8576 gh	3799 gh	957 klmn	62.7 gh	24 ijk	4.6 cde	48 jkl
		Guil	8918 e-h	3733 gh	1314 fgh	79.2 de	25 hij	4.4 de	52 ij
		Jonobi	9166 d-g	3797 gh	1607 bcd	80.5 de	26 g-j	4.7 bcd	65 de
		Gorgani	7561 i-l	3306ijk	906lmno	68.5fg	23jkl	4.4de	42m
	80%	Mesri	8402 g-j	3411 hijk	1443 def	84.9 cd	26 g-j	5.1 b	54 hi
		Guil	11110 b	4686 bc	1578 cde	85.0 cd	29 efg	5.0 bc	59 f
		Jonobi	7323 kl	3204 jk	8981 mno	52.4 ijk	25 hij	4.8 bcd	54 ghi
		Gorgani	7975 hijk	3656 ghi	743 o	44.4 lm	29 e-h	4.4 def	54 hi
	60%	Mesri	6197 mn	2823 lm	571 p	45.8 klm	21 kl	3.5 i-o	31 n
		Guil	531 1o	2422 n	495 p	42.5 lm	19 lm	3.9 f-i	30 n
		Jonobi	8626 gh	3916 fg	841 mno	42.5 lm	30 def	3.6 h-n	51 ijk
		Gorgani	8787 fgh	3772 gh	1292 fgh	63.5 gh	28 f-i	3.4 j-o	51 ijk
	40%	Mesri	10060 cd	4567 bcd	830 no	40.5 m	29 fgh	2.8 p	50 ijk
		Guil	5743 no	2604 mn	546 p	41.91 m	16 m	3.6 h-n	33 n
		Jonobi	9752 cde	4303 de	1063 ijkl	46.6 j-m	32 b-e	3.3 l-o	58 fg
		Gorgani	8460 ghi	3535 ghij	1265 gh	62.2 gh	28 f-i	3.9 g-k	50 ijk

Water productivity based on yield

Effect of year, effect of irrigation, effect of year×irrigation, effect of cultivars, effect of year ×cultivars, effect of irrigation×cultivars and effect of year×irrigation×cultivars were significant at 1% level on water productivity of biological yield and pod yield (Table 5). The highest amount of water productivity was obtained in biological yield with the treatment 40% water requirements with the mean of 2.92 kg m^{-3} (Table 7). For effect of year×irrigation, the maximum water productivity was in biological yield in 2018 and in 40% of the water requirement treatment with the mean of 3.65 kg m^{-3} (Figure 8). In different peanut cultivars, Jonobi cultivar with the mean of 2.6 kg m^{-3} had the highest water productivity in biological yield compared to other cultivars (Figure 9). For the effect of irrigation×cultivars, the highest value belonged to non-irrigation treatment and Jonobi cultivar with the mean of 3.29 kg m^{-3} (Figure 11). Maximum water productivity in biological yield was observed in effect of year×irrigation×cultivar in 2018, with 40% water requirements treatment in Mesri cultivar with a mean of 4.32 kg m^{-3} (Table 12). For the effect of irrigation, highest value of water productivity was for pod yield with 40% water requirements treatment with the mean of 1.28 kg m^{-3} (Figure 7). For the effect of year×irrigation, highest value of water productivity was in pod yield in 2018 with 40% water requirements treatment with the mean of 1.61 kg m^{-3} meter (Figure 8). Guil cultivar with the mean of 1.13 kg m^{-3} had the highest amount of water productive in pod yield among all peanut cultivars (Figure 9). For the effect of year×cultivar, Jonobi cultivar in 2018 had the highest value with the mean of 1.25 kg m^{-3} (Figure 10). For the effect of irrigation×cultivar, the highest values belonged to Jonobi cultivar with 40% water requirements treatment and Mesri cultivar with 40% water requirements treatment with the means of 1.43 kg m^{-3} and 1.44 kg m^{-3}, respectively (Figure 11). For the effect of year × irrigation×cultivar, the maximum water productivity was in pod yield in year 2018 and in 40% of the water requirement treatment in Mesri cultivar with the mean of 1.96 kg m^{-3} (Table 12). For the effect of irrigation, the highest water productivity belonged to seed yield, with 40% water requirements treatment with a mean of 0.35 kg m^{-3} (Figure 7). For the effect of year×irrigation, maximum water productivity was obtained in seed yield in 2018, with 40% water requirements treatment with a mean of 0.40 kg m^{-3} (Figure 8). In different peanut cultivars, Jonobi cultivar with the mean of 0.34 kg m^{-3} had the highest water productivity in seed yield compared to other cultivars (Figure 9). For the effect of year×cultivar, year 2018 and Gorgani cultivar had the highest value with a mean of 0.36 kg m^{-3} (Figure 10). For the effect of irrigation×cultivar, the highest values belonged to the treatment with 80% water requirement and the Guil cultivar with the mean of 0.41 kg m^{-3} and also in the 40% water requirements treatment and Gorgani cultivar with the mean of 0.40 kg m^{-3} (Figure 11). Maximum water productivity was obtained for seed yield for the effect of year×irrigation×cultivar in 2018 with the 40% water requirements treatment for Gorgani cultivar with the mean of 0.54 kg m^{-3} (Table 12). Puang Bat et al. (2010) examined eleven peanut cultivars in the irrigation conditions with and without stress. They concluded that water stress reduces seeds' water productivity from 1.69 kg m^{-3} under non-stress conditions to 0.98 kg m^{-3} under stress conditions. Water stress has a negative effect on many plant processes such as photosynthesis, evaporation, precursor accumulation and allocation (Ohashi et al., 2006), and leads to a substantial reduction in production (Reddy et al., 2004). Therefore, water stress is one of the methods to maximize water productivity and increase yield per unit of water consumed in deficit irrigation, in which the plant is put under stress conditions at a certain stage of growth or the whole duration of the growing season (Liu et al., 2008).

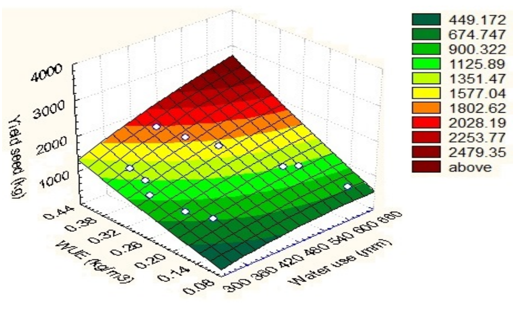
Table 12. Effect of year×water requirements×cultivars on agronomic traits measured in 2017 and 2018.

Year	water requirements	cultivars	Water productivity based on yield		
			Biomass	Pod	Seed
2017	100%	Mesri	1.67 d	0.76 mn	0.17 p
		Guil	1.94c d	0.84 lmn	0.27 jkl
		Jonobi	2.10 cd	0.90 jkl	0.32 g-j
		Gorgani	1.55 d	0.65 o	0.26 j-m
	80%	Mesri	2.70 cd	0.84l mn	0.35 e-i
		Guil	2.28 cd	0.92 ijkl	0.37 efg
		Jonobi	2.14 cd	0.91 ijkl	0.32 g-k
		Gorgani	2.13 cd	0.92 ijkl	0.32 g-k
	60%	Mesri	2.38 bcd	1.70 h	0.23 l-o
		Guil	2.46 bcd	1.80 h	0.31 g-k
		Jonobi	2.80 abcd	1.21 fg	0.41 cde
		Gorgani	2.15 cd	0.90 jkl	0.32 g-k
	40%	Mesri	2.13 cd	0.92 ijkl	0.35 f-i
		Guil	2.29 cd	1.10 hij	0.34 ghi
		Jonobi	2.4 bcd	1.20 hij	0.29 ijkl
		Gorgani	1.96 cd	0.87 lm	0.26 klmn
2018	100%	Mesri	1.89 cd	0.84 lmn	0.21 m-p
		Guil	1.97 cd	0.82 lmn	0.29 i-l
		Jonobi	2.20 cd	0.83 lmn	0.35 e-h
		Gorgani	1.67 d	0.73 no	0.20 nop
	80%	Mesri	2.32 cd	0.94 ijkl	0.40 def
		Guil	3.70 abcd	1.29 ef	0.44 bcd
		Jonobi	2.20 cd	0.88	0.25 lmn
		Gorgani	2.20 cd	1.10 hijk	0.21 m-p
	60%	Mesri	2.27 cd	1.30 hi	0.21 m-p
		Guil	1.94 cd	0.89 kl	0.18 op
		Jonobi	3.15 abcd	1.43 cd	0.31 h-k
	40%	Gorgani	3.21 abcd	1.38 de	0.47 b
		Mesri	4.32 a	1.96 a	0.36 efgh
		Guil	2.47 bcd	1.12 gh	0.23 l-o
		Jonobi	4.19 ab	1.85 b	0.46 bc
		Gorgani	3.63 abc	1.52 c	0.54 a

Evaluation of production function of peanut cultivars in conditions of complete irrigation and water stress

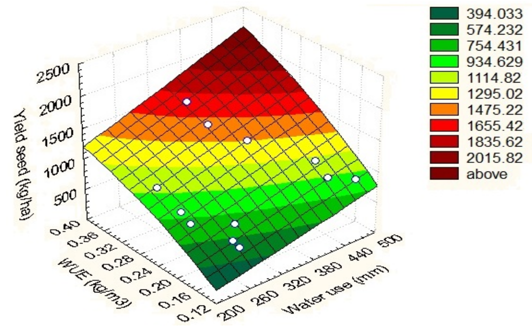
In this study all factors were assumed as fixed and crop yield was considered as a function for water requirement. Derivatives of the production function are the effects of two concepts of water use efficiency and amount of water consumed on the yield. The overall shape of the production function in this study is quadratic. Many researchers have examined the estimation of water demand function on crops, and they have suggested the quadratic function as the best production function (Abdzad Gohari et al., 2018; Amiri et al., 2015). Amount of water used and examination of the effect of deficit irrigation and water productivity on yield, represents the nonlinear quadratic equations in different peanut cultivars which can be seen in Figure 12.

Guil cultivar in 2017



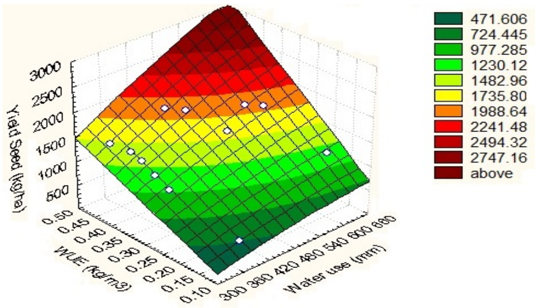
$$Y_{seed} = -665.276+3.204WU+47.657WUE-0.003WU^2+8.179 WU.WUE+1093.99WUE^2$$

Guil cultivar in 2018



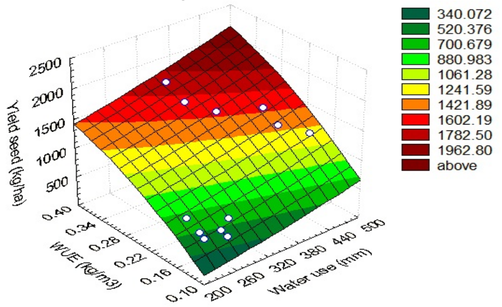
$$Y_{seed} = -722.707+1.027WU+5687.375 WUE+3.526e\text{-}4WU^2+5.121WU.WUE-6138.32WUE^2$$

Gorgani cultivar in 2017



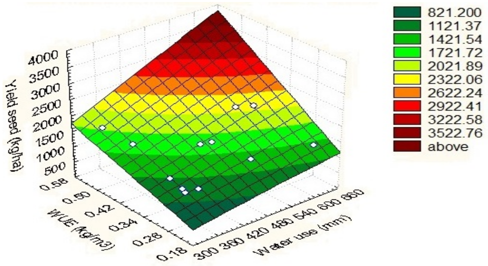
$$Y_{seed}= -682.716+2.562WU+818.54WUE-0.002WU^2+8.239WU.WUE-229.409WUE^2$$

Gorgani cultivar in 2018



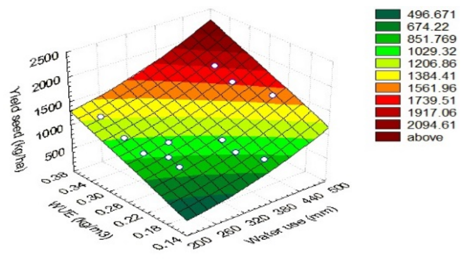
$$Y_{seed} = -86.175+0.458WU+7184.94WUE+0.001WU^2+ 2.544WU.WUE-7063.91WUE^2$$

Jonobi cultivar in 2017



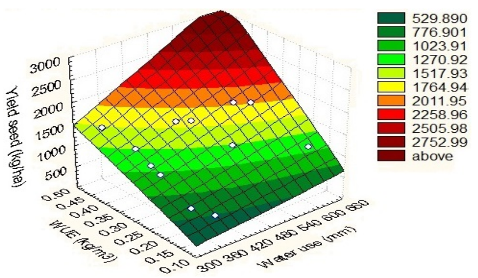
$$Y_{seed} = -137.098+0.492 WU+122.306 WUE-5.142e\text{-}4WU^2+9.919WU.WUE-26.005WUE^2$$

Jonobi cultivar in 2018



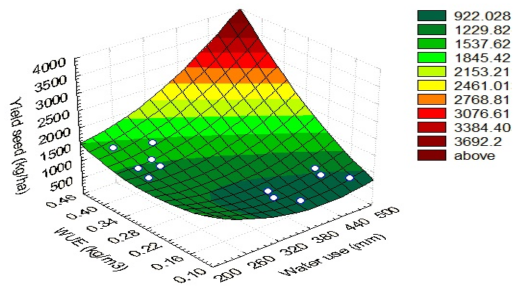
$$Y_{seed} = -275.88-1.115WU+ 4077.93WUE+0.005WU^2+1.867WU.WUE-759.608WUE^2$$

Mesri cultivar in 2017



$$Y_{seed} = 30.371-0.472WU+512.828WUE+6.084e\text{-}4WU^2+9.866WU.WUE-780.698WUE^2$$

Mesri cultivar in 2018



$$Y_{seed} =4968.76-18.936WU-12141.4WUE+0.02WU+29.633 WU.WUE +11463.35 WUE^2$$

Y: Yield (kg ha^{-1}), WU: Water use (mm) and WUE: Water use efficiency (kg m^{-3}).

Figure 7. Production Functions yield-Water productivity-Water use, in Peanut Cultivars in 2017 and 2018.

CONCLUSIONS

This study was conducted with the aim of optimization of water use in peanut cultivars under different irrigation managements. Increasing the amount of water to the optimum level of consumption is result in the increase in peanut yield. According to the analysis of the results, the amount of water consumed and the amount of water productivity is effective on the amount of yield. By increasing irrigation up to 80% of water requirement, in Guil cultivar, biological yield (10880 kg.ha^{-1}) and pod yield (4502 kg .ha^{-1}) and seed yield (1667 kg.m^{-3}) increased. Water productivity on biological yield (4.32 kg m^{-3}) and pod yield (1.96 kg.m^{-3}) in Mesri cultivar and Water productivity on seed yield in Gorgani cultivar were 0.54 kg.m^{-3}. The coefficients obtained from water production function of the consumed water on the yield in irrigation conditions, indicated that supplying the proper amount of water will maximize the yield production and supplying 100% of the required water will maximize the yield in peanut cultivars.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interest or personal relationships.

STATEMENTS AND ACKNOWLEDGEMENTS

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

LITERATURE CITED

Abdzad Gohari, A., H. Babazadeh, E. Amiri and H. Sedghi. 2018. Estimate of Peanut Production Function under Irrigated Conditions and Salinity. Polish Journal of Environmental Studies. *27*(4).

Allen, L.H.J., K.J. Boote, and L.C. Hammond. 1976. Peanut stomatal diffusive resistance affected by soil water and solar radiation. Proc. Soil Crop Sci. Soc. Fla. 35: 42–46.

Amiri, E., A.G. Abdzad and A. Mianabadi. 2015. Evaluation of water schemes for peanut, using CSM-CROPGRO-Peanut model. Archives of Agronomy and Soil Science. 61(10):1439-1453.

Anjum, N.A., S.S. Gill and R. Gill, eds. 2014. Plant adaptation to environmental change: significance of amino acids and their derivatives. CABI.

Balota, M. 2020. Rainout Shelter-Induced Water Deficit Negatively Impacts Peanut Yield and Quality in a Sub-Humid Environment. Peanut Science. 47(2): 54-65.

Bonari, E., G.P.V. Vannozzi, A. Benvenuti and M. Baldini. 1992. Modern aspects of sunflower cultivation technigues. Proc. 12th, Sunf, Pisa. Italy.

Boontang, S., T. Girdthai, S. Jogloy, C. Akkasaeng, N. Vorasoot, A. Patanothai and N. Tantisuwichwong. 2010. Responses of released cultivars of peanut to terminal drought for traits related to drought tolerance. Asian J. Plant Sci. 9:423–431.

Boote, K.J. and G.P.V. Ketring. 1990. Peanut. In: Stewart, B.A., Nielsen, D.R. (Eds.), Irrigation of Agricultural Crops. ASA, CSSA, SSSA, Madison, WI. 675–717.

Canavar O. and M.A. Kaynak. 2010. Growing degree day and sunshine radiation effects on Peanut pod yield and growth. Afr. J. Biotechnol. 9:2234–2241.

Capra, A., S. Consoli and B. Scicolone. 2008.Water Management Strategies under Deficit Irrigation, J. of Ag. Eng. - Riv. di Ing. Agr .4:27-34.

Kvien, C.K., C.C. Holbrook, P. OziasAkins, C. Pilon, A.K. Culbreath and T.B. Brenneman. 2019. Peanut production guide Peanut Physiology. University of Georgia. In press.

Anjum, S. A., X.Y. Xie, L.C. Wang, M.F. Saleem, C. Man, and W. Lei. 2011. Morphological, physiological and biochemical responses of plants to drought stress. African journal of agricultural research, 6(9), 2026-2032.

Doorenbos, J. and A.H. Kassam. 1979. Yield response to water. FAO Irrigation and Drainage. Rome, Italy.33: 193.

Fulmer, A.M., T.B. Brenneman, R.C. Kemerait, R. Macajoux, D.A. Carroll, G. Faroutine, W. Sheard, P. Dorzan, J.A. Rhoads and G.E. MacDonald. 2020. Evaluation of Improved Valencia Peanut Varieties for Production in Haiti. Peanut Science. 47:1–8.

Geerts, S. and D. Raes. 2009. Deficit irrigation as an on-farm strategy to maximize crop water productivity in dry areas. Agr. Water Manage. 96:9. 1275-1284.

Hammons, R.O., D. Herman, H.T. Stalker. 2016. Origin and early history of the peanut. In Peanuts: Genetics, Processing, and Utilization. AOCS Press, San Diego, CA.1-26.

Hawkins, G.L. J. Kelton, N. Smith and K.A. Balkcom. 2016. Note on Comparing Rate of Soil Moisture Loss for Conventional and Conservation Tillage Production methods for Peanut (*Arachis hypogaea* L. Peanut Science. 43:168–172.

Howell, T.A., M.J. McFarland, D.L. Reddell, K.W. Brown, R.J. Newton, P. Dahmen. 1980. Response of peanuts to irrigation management at different crop growth stages. Texas Water Resources Inst., TR-113 vol. II, Texas A&M University, Stephenville, TX.

Ike, I. 1986. Effects of soil moisture stress on the growth and yield of Spanish variety peanut. Plant Soil. 96: 297–298.

Nayak, J.J., P.D. Gajjar, S.M. Basha and K.S.S. Naik. 2019. Interrelationship between stilbene producing ability and Aspergillus colonization on selected peanut (Arachis hypogaea L.) genotypes. Peanut Science. 46:118–126.

Kijne, J. W., T.P. Toung, J. Bennett, B. and T. Oweis. 2003. Ensuring food security via improvement in crop water productivity. CGIAR challenge program on water and food (CP), Background paper.

Kvien, C.K., C.C. Holbrook, P. Ozias-Akins, C. Pilon, A.K. Culbreath, and T.B. Brenneman. 2019. Peanut production guide, Peanut Physiology. University of Georgia. In press.

Lambers, H., F.S. Chapin and T.L. Pons. 2008. Photosynthesis. Plant physiological ecology, Springer. 11-99.

Liu, X.Q., K.Y. Ko, S.H. Kim and K.S. Lee. 2008. Effect of Amino Acid Fertilization on Nitrate Assimilation of

Leafy Radish and Soil Chemical Properties in High Nitrate Soil. Communications in Soil Science and Plant Analysis 39: 269–281.
Lenka, D. and P.K. Mishra. 1973. Response of groundnut (Arachis hypogaea L.) to irrigation. Indian J. Agron. 18: 492–497.
Meisner, C.A. and K.J. Karnok. 1992. Peanut root response to drought stress. Agron. J. 84: 159–165.
Narasimham, R.L., I.V.S. Rao and S.M. Rao. 1977. Effect of moisture stress on response of groundnut to phosphate fertilization. Indian J. Agric. Sci. 47: 573–576.
Nautiyal, P.C., S. Ravindra and Y.C. Joshi. 1991. Physiological and biochemical basis for viability differences in Spanish groundnut in response to soil moisture stress. Oleagineux 46: 153–158.
Nautiyal, P.C., Y.C. Yoshi and D. Dayal. 2000. Deficit irrigation practices. FAO Water reports. 22:102.
Ong, C.K., 1984. The influence of temperature and water deficits on the partitioning of dry matter in groundnut (Arachis hypogaea L.). J. Exp. Bot. 35: 746–755.
Ohashi Y., N.S.H. Nakayama and K. Fujita. 2006. Effects of drought stress on photosynthetic gas exchange, chlorophyll fluorescence and stem diameter of soybean plants. Journal of Biology Plant. 50:138-141.
Pallas, J.E., J.R. Stansell and T.J. Koske. 1979. Effects of drought on florunner peanuts. Agron. J. 71:853–858.
Pierre, A.K., M.J. Mulvaney, D.L. Rowland, B. Tillman, T.L. Grey, J.E. Iboyi, R.G. Leon, D. Perondi and C.W. Wood. 2019. Foliar Fertilization as a Strategy to Increase the Proportion of Mature Pods in Peanut (*Arachis hypogaea* L.). Peanut Science. 46:140–147.
Puangbut D., S. Jogloy, N. Vorasoot, C. Akkasaeng, T. Kesmala and A. Patanothai. 2009. Variability in yield responses of peanut (*Arachis hypogaea* L.) genotypes under early season drought. Asian Journal. Plant science. 8: 254-264.
Rao, R.C.N., J.H. Williams, M.V.K. Sivakumar, K.D.R. Wadia. 1988. Effect of water deficit at different growth phases of peanut. II. Response to drought during preflowering phase. Agron. J. 80: 431–438.
Reddy, C.R. and S.R. Reddy. 1993. Scheduling irrigation for peanuts with variable amounts of available water. Agric. Water Manage. 23: 1–9.
Raddy A.R. Chaitanya K.V. and Vivekanandan M., 2004. Drought induced responses of photosynthesis and antioxidant metabolism in higher plant. Journal of Plant Physiology. 161:1189-1202.
Shinde, B.M. and L., Laware., 2010. Effect of drought stress on agronomic Contributing characters in Groundnut (Arachis hypogea L.. Asian. J. Exp. Biol. Sci. 2: 968-971.
Steel, R.G.D. and J.H. Torrie. 1980. Principles and procedures of statistics. A biometrical approach, 2nd Edition, McGraw-Hill Book Company, New York.
Virk, G. C. Pilon and J.L. Snider. 2019. Impact of First True Leaf Photosynthetic Efficiency on Peanut Plant Growth under Different Early-Season Temperature Conditions. Peanut Science. 46:162–173.