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Original Research

Estimate of Peanut Production Function under Irrigated Conditions and Salinity

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Abstract

Salinity is one of the main and common challenges in the world. This study was conducted to determine the effect of salinity and water requirements of peanuts, with main factors including water requirement 40% (WR_4), 60% (WR_3), 80% (WR_2), and 100% (WR_1); sub-treatment including salinity with values of 1 (S_1), 3 (S_2), 5 (S_3), and 7 (S_4) dS/m; and sub-sub-treatment including four cultivars Guil (V_1), Gorgani (V_2), Jonobi (V_3), and Mesri (V_4). The experimental design was conducted in the form of split factorial in a completely randomized block with 3 replications in 2015 and 2016. The results showed that the maximum seed yields in salinity levels of 1 dS m^{-1} in 2015 and 2016 were 1,142 and 987 kg ha^{-1}, respectively. On the interaction effect of irrigation and salinity, maximum seed yields in 80% water requirement and salinity of 1 dS m^{-1} in 2015 and 2016 were 1,393 and 1,265 kg ha^{-1}, respectively. The maximum seed yields in Jonobi cultivar with salinity of 1 dS m^{-1} and in Guil cultivar in salinity of 5 dS m^{-1} were 1,254 and 1,127 kg ha^{-1}, respectively. The Guil cultivar in 100% water requirement and with salinity of 1 dS m^{-1} in 2015 and 2016 had the highest seed yield, with 1,883 and 1,710 kg ha^{-1}, respectively.

Keywords: irrigation, peanut cultivars, yield, water requirement

Introduction

The peanut is one of the most important and economic oil seeds in tropical and subtropical areas. It is rich in minerals, vitamins, fatty acids, fiber, and phenolic compounds [1-2]. It is also a good source of protein for humans and livestock, and it plays an important role in improving the fertility of soil by fixing atmospheric nitrogen [3]. In terms of climate, Iran is located in an arid and semi-arid region. Limited water resources and appropriate and scattered distribution of rainfall have made it essential to use water efficiently and optimally in the agricultural sector. The importance of water is undeniable in the production of the peanut and it is essential in the colloidal structure of protoplasm and performing metabolic activities [4-5]. We examined the yield of peanut genotypes at different irrigation levels and have reported that seed yield is reduced significantly by reducing the number and volume of irrigation, so that the lack of irrigation in a peanut plant reduced 21% of seed yield per hectare compared to full irrigation conditions [3]. It is necessary to determine the exact water requirements of the peanut since we can improve water management for this plant [6].

The peanut is relatively tolerant against drought, and its roots have ability to absorb water from soil depths

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Table 1. Meteorological data.

During growth	Maximum Temperature (ºC)		Minimum Temperature (ºC)		Wind Speed (m s^{-1})		Minimum Humidity (%)		Maximum Humidity (%)	
	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015
May	25.2	24.5	13.7	14.8	2.2	2.1	90	89	79	75
Jun	27.3	28.4	17.3	18.4	1.2	2.4	92	90	55.5	58.9
Jul	41.9	31.9	20	19	1.9	1.8	85.9	93.4	66.9	49
August	29.5	28.9	18.8	20.2	1.3	2.9	95.4	89	71	61.9
September	28.4	27.3	18.5	19.2	1.9	2.8	91.3	88	58	63.8

[4]. Peanut cultivars show different reactions to water stress in different growth stages, and the value of water has a significant impact on the growth of pods. High soil moisture is required to develop peanuts at all stages of growth. However, under limited water conditions, irrigation scheduling in critical stages can increase yield and water use efficiency in peanut [4]. Salinity is one of the plants limiting stresses around the world, and achieving salt-tolerance is highly desirable in today's agricultural context [7-8]. Since most crop species are sensitive to salt, salinity has become a serious threat to agriculture, especially in arid, semi-arid, and coastal areas of world, because it limits plant growth and productivity [9-10]. Salinity is also one of the major problems that has made a large part of lands uncultivable. Approximately one third of the world's cultivable irrigated lands are affected by salinity, a rate that is rising [11]. Using saline water is one of the key strategies for optimizing the use of water, and this has high priority.

The peanut is relatively sensitive to soil and water salinity, and salinity reduces seed germination, growth, and dry matter production [11-12]. The production function is a purely physical concept and it simply shows the relationship between inputs and outputs of production. This function describes the maximum yield obtained by different combinations of inputs. Therefore, in this regard, we should think not only of product yield, but proper use of resources has greater importance. By estimating the agricultural production function and information obtained from it, we can determine the production capacity and compare it with actual yield. This comparison provides the conditions for identifying the major problems in this sector and comprehensive understanding of the main factors involved in it. Estimating the production function also makes it possible to determine the role and importance of production inputs separately.

The peanut is one of the most important plants in the northern Iran (Guilan Province), which determines water requirement, and identifying cultivars tolerant to salinity is very important in this plant. The objective of this study was to examine the efficiency of water use and to estimate the production function of peanut cultivar in different levels of salinity.

Material and Methods

The present experiment was conducted in northern Iran at latitude 37°25´ and longitude 49°94´, and with average height of 5 m above sea level in 2015 and 2016 in twice-split plots, and based on completely randomized blocks designed in 3 replications. The city is considered among the more mild and humid areas in terms of climate. Rainfall during the growing season in 2015 and 2016 was 232.8 and 349.6 mm, respectively (Table 1). Before preparing the land, sampling was randomly performed from soil of different points of the farm at two depths: 0-20 and 20-40 cm (Table 2).

The time to sow seeds in both years was 10 May and harvest time was the 20 September. Each study subject had dimensions of 4×2.5 m with 6 cultivation rows. In this study, the main factor was water requirements of 40 (WR_4), 60 (WR_3), 80 (WR_2), and 100 (WR_1) percent, and sub-treatment included salinity of levels 1 (S_1), 3 (S_2),

Table 2. Characteristics of soil in the study area

Particle size distribution %									
Crop years	Soil depth (cm)	Sand	Silt	Clay	Organic Carbon	Soil texture	Bulk density (g cm^{-3})	Permanent Wilting Point (%)	Field Capacity (%)
2015	0-20	49	32	19	0.68	Loamy	1.25	14.7	27.1
	20-40	49	31	20	0.66	Loamy	1.33	14.2	28.5
2016	0-20	45	38	17	0.36	Loamy	1.25	14.7	27.1
	20-40	45	38	17	0.30	Loamy	1.33	14.2	28.5

Table 3. Amount of water use in each treatment in 2015 and 2016.

Year	2015	2016	2015	2016
Water requirements	Amount of irrigation (mm)		Amount of water use (mm)	
40%	108	121	340.5	470.6
60%	145	171	377.8	520.3
80%	163	202	395.5	551.3
100%	222	238	454.8	587.9

5 (S_3), and 7 (S_4) dS m^{-1}, and sub-sub-treatment included four cultivars of peanut, including Guil (V_1), Gorgani (V_2), Jonobi (V_3), and Mesri (V_4). To determine the irrigation treatments, soil moisture discharge was used and water requirement of plant was considered as 100% irrigation treatment, and other irrigation treatments were considered as a percentage of this value. The duration and value of irrigation at each stage were determined with depth of the root and measuring the soil moisture using a weight method in the relevant layer at any stage of irrigation. Soil moisture in the root depth using Equation (1) was calculated for soil moisture to reach the capacity limit of the farm. The duration of irrigation was also calculated after reaching the water to moisture front in the plant root depth.

$$d_n = (\theta_{fc} - \theta_i).\rho_b.D_r \quad (1)$$

...where: θ_{fc}: moisture at field capacity (%), θ_i: moisture content in the soil (%), ρ_b: bulk density (g cm^{-3}), and D_r: root depth (cm). Measuring the amount of water delivered to every plot was performed by flow meters. The amounts of water during growing were obtained through irrigation and rainfall (Table 3).

To determine the yield in each plot, after removing two rows from both sides, 12 plants were randomly selected and placed within the oven at a temperature of 70ºC for 48 hours. After drying, the samples were weighed with one hundredth of a weight precision scale. In each plot, after deleting the rows from both sides, 12 plants were randomly selected. To determine the weight of 100 seeds, 200 g of pod was selected as samples, and 100 seeds were randomly selected and their weight was recorded by a scale (g). To determine the length of seed in each plot, 50 seeds were randomly selected and they were measured by a caliper. To determine the height of plants, 12 plants were randomly selected from each plot and they were measured by a ruler. Product yield may be written as a function of water and salinity. When the production function is expressed in the form of an equation, the optimal value of function variables can be determined. To determine the production function in the form of a two-variable function, yield data against water and salinity were ordered. The best fit of used-yield

Table 4. Mean squares form the combined ANOVA for seed yield, 100-seed weight, number of pods per shrub, seed length, and plant height.

Source	df	Seed yield		100-seed weight		Number of pods per shrub		Seed length		Plant height	
		2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Replication	2	862,423.01^{ns}	7,931.193^{ns}	164.140^{ns}	21.672^{ns}	4,922.149^{ns}	17.225^{ns}	4.277^{ns}	0.033^{ns}	2.957^{ns}	43.149^{ns}
WR	3	1,209,275.4^{ns}	1,127,519*	480.202^{ns}	68.229^{ns}	5,945.665*	7,112.679*	5.712*	6.201*	8.768*	3,351.81*
Error	6	210,962.26	233,702.94	298.445	198.109	746.938	956.287	1.553	1.026	1.519	943.637
S	3	765,818.12**	122,802.46**	99.334**	63.479**	2,260.619**	784.920**	1.845**	0.870**	0.353**	101.579**
WR×S	9	56,134.839*	339,888.2**	133.361**	166.484**	355.664**	560.131**	0.130**	0.330**	0.473**	53.174**
V	3	87,799.894*	105,379.88**	17.262^{ns}	67.229^{ns}	203.542**	375.159**	0.065*	0.151**	0.076**	32.840^{ns}
WR×V	9	417,620.913**	334,863.843**	44.689**	74.697**	1,232.660**	902.470**	0.014^{ns}	0.081**	0.191**	53.165**
S×V	9	345,982.866**	222,561.843**	118.450**	91.502**	907.474**	420.541**	0.369**	0.153**	0.851**	43.779**
WR×S×V	27	78,930.897**	191,632.899**	20.322*	65.495*	158.345**	371.477**	0.104**	0.265**	0.163**	49.327**
Error	120	29,703.759	1,036.383	11.083	0.517	50.74	1.92	0.029	0.002	0.052	0.026
CV (%)		7.5	3.5	2.7	3.5	2.7	3.9	2.3	8.1	11.4	0.88

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

Table 5. Mean comparison of the effects of WR and S treatments on parameters of seed yield, 100-seed weight, number of pods per shrub, seed length, and plant height.

Treatments	Seed Yield (kg ha^{-1})		100-seed weight (g)		Number of pods per shrub		Seed length (cm)		Plant height (cm)	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
WR_1	1,052a	1,032ab	27a	27a	70ab	68ab	2.5a	2.4a	66.2b	64.9ab
WR_2	1,177a	1,169a	30a	27a	77a	70a	2.3ab	2ab	72.4a	65.7a
WR_3	888a	782c	25a	25a	58bc	49b	2 ab	1.6b	56.2c	50.1b
WR_4	827a	791bc	23a	25a	53c	47b	1.7b	1.7b	51.9d	51.6ab
S_1	1142a	978a	27a	26c	73a	63a	2b	1.9c	63.4a	59.2b
S_2	979b	906c	24b	25d	66b	60b	2.4a	2.1a	60.5c	56.9c
S_3	991b	932b	27a	27a	61c	56c	2b	1.9b	62.9b	59.5a
S4	833c	857d	26ab	26b	57d	55c	2b	1.8d	59.8d	56.7d

salinity and water explaining the production function is as follows:

$$Y(wu, s) = a_0 + a_1 wu + a_2 s \quad (2)$$

…where Y is yield (kg ha^{-1}), WU is the amount of water (mm), S is salinity (dS m^{-1}), and a_0 and a_1 are constants of the equation. Variance analysis and comparing the data were performed by MSTAT-C software, and production function coefficients were estimated by STATISTICA 5.5 software.

Results and Discussion

Seed Yield

The effect of irrigation on seed yield in 2015 and 2016 was significant at the probability level of 5%. Salinity values' effects on seed yield were significant in 2015 and 2016 at a probability level of 5%. The interaction effect of irrigation and salinity on seed yield was significant in 2015 at the probability level of 5%, while the interaction effect of irrigation and salinity was significant in 2016 at the probability level of 1% (Table 4). The maximum seed yield in 2015 in treatment of 80% of water requirement was 1,169 kg ha^{-1}, respectively (Table 5). The maximum seen yield in 2015 and 2016 at salinity level of 1 dS m^{-1} was 1,142 and 978 kg ha^{-1}, respectively (Table 5). Seed yield in 2015 and 2016 in treatment of 80% of the water requirement and salinity level of 1 dS m^{-1} was 1,393 and 1,265 kg ha^{-1}, respectively (Table 6). The effect of peanut cultivars on seed yield in 2015 was significant at the probability level of 5%, while it was significant at the probability of 1% in 2016 (Table 4). The yield in the Guil cultivar was 1,008 kg ha^{-1} in 2015, and in the Jonobi cultivar 970 kg ha^{-1} (Table 7). The interaction effect of irrigation and cultivars and the interaction effect of salinity and cultivars and the combined effect of irrigation, salinity, and cultivars on seed yield in 2015 and 2016 were significant at probability level of 5% (Table 4). The seed yield in interaction effect of irrigation and cultivars in treatment of 80% water requirements and Guil cultivar in 2015 and 2016 were 1,483 and 1,347 kg ha^{-1}, respectively (Table 8). On the interaction effect of salinity and cultivars in 2015, Jonobi cultivar with salinity of 1 dS m^{-1} showed a yield of 1,254 kg ha^{-1}, and Guil cultivar yield in 2016 with salinity of 5 dS m^{-1} was 1,127 kg ha^{-1} (Table 9). Seed yield in combined effect of irrigation, salinity, and cultivars in the Guil cultivar and in treatment of 100% water requirement and salinity of 1 dS m^{-1} in 2015 and 2016 was 1.883 and 1,710 kg ha^{-1}, respectively (Table 10). Several reports have indicated that seed germination, seedling emergence, and early survival are susceptible to salinity and peanut cultivars in no-water stress conditions, stress at the stage of growth, stress in the flowering stage, stress in the seed-filling stage, and rain-fed treatment [13]. They reported that peanut yield is significantly affected by the value of water used. Salinity affects the growth and productive stage of a plant and it decreases dry weight and yield. Salinity negatively affects the physiological process, including water relations, and gas exchange attributes a nutritional imbalance and disturbs the stability of membranes [14]. Reduced yield in salinity conditions is due to disruption in absorption of nutrients, ion imbalance, or decreased water potential in soil and osmotic stress in photosynthesis activities of a plant [15]. In a study it was reported that the supply of a water requirement during growing season increases seed yield in peanut [16]. The effects of salinity can be in the stage of pod filling and seed growth stage, so the number and weight of seeds are two important components of seed yield that are reduced due to salinity [17].

100-seed Weight

The effects of salinity, the interaction effect of irrigation and salinity, the interaction effect of irrigation, and the interaction effect of salinity and cultivars on the weight of 100 seeds were significant in 2015 and 2016 at probability

Table 6. Reaction of WR×S treatments on parameters of seed yield, 100-seed weight, number of pods per shrub, seed length, and plant height.

WR×S		Seed Yield ($kg\ ha^{-1}$)		100-seed weight (g)		Number of pods per shrub		Seed length (cm)		Plant height (cm)	
		2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
WR_1	S_1	1,283ab	1,258a	33a	32a	76b	74b	2.3c	2.3c	67.9b	66.6b
	S_2	1,082cde	1,061c	24def	24h	77b	75b	2.8a	2.7a	67.2b	65.9bc
	S_3	1,027def	1,007d	30b	30c	64c	62d	2.3c	2.3c	65.5bc	64.3c
	S_4	816hi	800h	22f	22i	64c	63d	2.4b	2.4b	64bc	62.8d
WR_2	S_1	1,393a	1,265a	28bc	26f	94a	86a	2.2d	2.0d	75.3a	68.4a
	S_2	1,134cd	1,030d	29b	26f	75b	68c	2.7a	2.4b	68.7b	62.4d
	S_3	1,204bc	1,093b	30b	27e	76b	69c	2.1e	2.0d	75.6a	68.7a
	S_4	977efg	887f	34a	31b	63c	57e	2.0f	1.8f	69.8b	63.4cd
WR_3	S_1	950e-h	563k	26cd	20j	61d	47h	1.9g	1.5i	56.6c	48.1g
	S_2	882gh	709j	22f	24h	62cd	49g	2.2d	1.7g	56.4c	48.7g
	S_3	906fgh	875f	28bc	29d	54e	47h	1.9g	1.7g	57.1c	53.7e
	S_4	816hi	979e	22f	27e	56de	54f	2.0f	1.5i	54.9cd	50.1f
WR_4	S_1	941fgh	826fg	22f	25g	61d	48g	1.7i	1.9e	53.9cd	53.5e
	S_2	818hi	823gh	22f	25g	52e	49g	1.8h	1.7g	49.8d	50.7f
	S_3	826hi	751ij	22f	24h	51ef	45i	1.6j	1.8f	53.4cd	51.5f
	S_4	723i	762i	25de	26f	46f	47h	1.5k	1.6h	50.4d	50.7f

level of 1%. The combined effects of irrigation, salinity, and cultivars of peanut on the weight of 100 seeds was significant in 2015 and 2016 at probability level of 5% (Table 4). The weight of 100 seeds in salinity of 1 and 5 dS m^{-1} in 2015 was 27 g and in 2016 was 27 g (Table 5). The weight of 100 seeds in 2015 and 2016 in treatment of 100% water requirement and salinity level of 1 dS m^{-1} was 33 and 32 g, respectively (Table 6). The weight of 100 seeds in treatment of 80% water requirement and Mesri cultivar in 2015 and 2016 were 33 and 30 g, respectively (Table 8). The weight of 100 seeds in Guil cultivar in 2015 in salinity of 1 dS m^{-1} obtained 31 g, while the weight of 100 seeds in this cultivar in 2016 in salinity of 5 dS m^{-1} was 30 g (Table 8). The weight of 100 seeds in 2015 and 2016 in 100% water requirement and salinity level of 1 dS m^{-1} in the Guil cultivar obtained 42 and 39 g, respectively (Table 10). The effect of water shortage on the weight of 100 seeds in the growth stages was different, and as the value of stress approaches reproductive growth, its negative effect will be higher. The reduction in the weight of 100 seeds due to salinity and water shortage has an unfavorable effect on the transfer of photosynthetic substances [14].

Number of Pods per Shrub

The effects of irrigation at probability level of 5% and salinity, interaction effect of irrigation and salinity, peanut cultivars, interaction effect of irrigation and cultivars, interaction effect of salinity and cultivars, and the combined effect of irrigation, salinity, and peanut cultivars on the number of pods in a plant were significant in 2015 and 2016 at 95% probability level (Table 4). The numbers of pods in 80% water requirement in 2015 and 2016 were 77 and 70, respectively, and at salinity

Table 7. Mean comparison of peanut cultivars on seed yield, 100-seed weight, number of pods per shrub, seed length, and plant height.

Treatments	Seed Yield ($kg\ ha^{-1}$)		100-seed weight (g)		Number of pods per shrub		Seed length (cm)		Plant height (cm)	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
V_1	1,008a	934b	26b	26b	66a	67a	2.1a	1.9d	61.5b	57.8c
V_2	966b	858d	26b	25c	62c	63d	2.1a	1.7c	62.5a	58.7b
V_3	1,033b	970a	27a	28a	63b	64c	2b	2a	61.7b	57d
V_4	937c	911c	26b	25d	67a	68a	2b	1.8b	61b	58.8a

Table 8. Reaction of WR×V treatments on parameters of seed yield, 100-seed weight, number of pods per shrub, seed length, and plant height.

WR×V		Seed Yield ($kg\ ha^{-1}$)		100-seed weight (g)		Number of pods per shrub		Seed length (cm)		Plant height (cm)	
		2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
WR_1	V_1	820ef	805i	27de	26e	57e	56h	2.5a	2.4a	64.8f	63.6g
	V_2	1,035d	1,015e	28bcd	28d	67d	66e	2.5a	2.4a	66.6e	65.3e
	V_3	1,278b	1,253b	30b	29b	75c	74c	2.5a	2.4a	67d	65.7d
	V_4	1,074cd	1,053d	25ef	24i	81b	80b	2.4b	2.4a	66.2e	65f
WR_2	V_1	1,483a	1,347a	29bcd	26e	94a	86a	2.2c	2d	73.5ab	66.8b
	V_2	1,197bc	1,088c	30bc	27d	76bc	69d	2.3bc	2.1c	74a	67.2a
	V_3	1,033d	939f	28bcd	26fg	70cd	64f	2.3bc	2.1c	72.8cb	66.1c
	V_4	993d	902g	33a	30a	68d	62g	2.2c	2d	69.2c	62.8h
WR_3	V_1	751f	781i	25ef	26fg	51fg	51i	2d	1.5i	55.2h	49.5n
	V_2	822ef	616k	24f	22j	55ef	46k	2d	1.6h	56.5g	50m
	V_3	1,039d	833h	27cde	27d	59e	45l	2d	1.7g	56.1gh	48.4o
	V_4	941de	897g	23f	25h	67d	56h	2d	1.6h	57.1g	52.7j
WR_4	V_1	977d	804i	23f	26ef	61e	47j	1.6f	1.6h	52.4i	51.6l
	V_2	810ef	713j	23f	26g	51fg	44l	1.7e	1.6h	52.9i	52.2k
	V_3	781f	855h	23f	28c	49g	47jk	1.7e	1.9e	50.8j	48p
	V_4	740f	790i	23f	21k	50fg	52i	1.6f	1.8f	51.4ij	54.7i

Table 9. Reaction of S×V treatments on parameters of seed yield, 100-seed weight, number of pods per shrub, seed length, and plant height.

S×V		Seed Yield ($kg\ ha^{-1}$)		100-seed weight (g)		Number of pods per shrub		Seed length (cm)		Plant height (cm)	
		2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
S_1	V_1	1,042cd	1,079b	31a	30a	71b	69a	2.2d	2d	59.9e	57.6bc
	V_2	1,222ab	1,007c	28bc	26e	75ab	64b	2.1e	2d	64b	59.5b
	V_3	1,254a	1,088b	30ab	29b	74b	64b	2.1e	2.1c	63.6b	59b
	V_4	1,087bcd	868f	24ef	22i	77a	64b	1.9g	1.7h	62.6bc	59.3b
S_2	V_1	965def	840g	24ef	24g	69c	60d	2.3c	2.1c	63.8b	59.4b
	V_2	1,119abc	872f	24ef	22i	75ab	64d	2.3c	2d	66.5a	62.1a
	V_3	1,048cd	981d	25de	28c	63ef	57e	2.5a	2.2b	60.8d	55.8b
	V_4	783ghi	930e	25de	26e	58g	61cd	2.4b	2.3a	57.5f	56c
S_3	V_1	1,189ab	1,127a	28bc	29b	68cd	62c	2.2d	1.9f	59.3e	57.6bc
	V_2	835fgh	890f	27cd	28c	50i	52h	2.2d	2d	59.9e	56.6c
	V_3	1,103bcd	944e	30ab	29b	64e	55f	1.9g	2d	61.8c	56.2c
	V_4	836fgh	766h	24ef	23h	62f	54fg	1.7i	1.8g	63.9b	62.3a
S_4	V_1	873efg	821g	25de	25f	59g	55f	1.8h	1.7h	59.2e	55.6c
	V_2	689i	662i	25de	26e	47j	44i	1.9g	1.8g	59.6e	56.6c
	V_3	727hi	867f	22f	26e	53h	53gh	2d	1.9f	60.5d	57.2bc
	V_4	1,005cde	950e	27cd	27d	67d	63bc	2d	2d	63.6b	58.8c

Table 10. Reaction of WR×S×V treatments on parameters of seed yield, 100-seed weight, number of pods per shrub, seed length, and plant height.

WR×S×V			Seed Yield (kg ha^{-1})		100-seed weight (g)		Number of pods per shrub		Seed length (cm)		Plant height (cm)	
			2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
WR_1	S_1	V_1	1,883a	1,710a	32d-g	32e	107a	97a	2.2e-h	2.2f	71.0f	69.6c
		V_2	1,356b-f	1,331e	36bcd	35c	78ef	77f	2.6bcd	2.5c	67.0ij	65.7g
		V_3	1,599b	1,568b	38abc	37b	84de	82e	2.4d-g	2.3e	66.3jk	65.0g
		V_4	984i-r	893pqr	42a	39a	73fgh	66h	2.1h-l	2.1g	67.5ij	66.2f
	S_2	V_1	857n-w	841rst	24o-u	23op	66h-n	65h	2.8ab	2.8a	70.3fg	69.0c
		V_2	1,195b	1,172ghi	25m-t	24mno	85de	83e	2.7bc	2.6b	63.1lm	61.9k
		V_3	1,463bcd	,1435c	26l-s	25lm	85de	83e	2.8ab	2.8a	69.0gh	67.7e
		V_4	813o-x	797tu	22s-w	22p	72fgh	71g	2.8ab	2.8a	66.4jk	65.1g
	S_3	V_1	817o-x	802t	28h-o	28ij	52p-y	51mno	2.6bcd	2.5c	58.2op	57.1n
		V_2	1,002h-r	9,82lmn	31d-h	31ef	56n-u	55jk	2.2e-h	2.2f	69.9gh	68.5d
		V_3	1,374b-f	1,348de	39ab	37b	71f-i	69g	2.2e-h	2.2f	68.9hi	67.5e
		V_4	914l-v	896opq	22s-w	22p	77efg	76f	2.1h-l	2.1g	65.2kl	63.9i
	S_4	V_1	764p-x	749uv	24o-u	23op	62i-o	60i	2.2e-h	2.2f	59.7no	58.5m
		V_2	588wx	577yz	20vwx	20qr	51q-y	50m-p	2.5cde	2.4d	66.5jk	65.2g
		V_3	675t-x	662yz	17x	17t	62i-o	60i	2.5cde	2.4d	63.9lm	62.7j
		V_4	1,235d-i	1,212g	28h-o	28ij	84de	82e	2.6bcd	2.5c	65.8kl	64.6h
WR_2	S_1	V_1	1,432b-e	1,300ef	25m-t	23op	104ab	94b	2.3efg	2.1g	73.0d	66.3f
		V_2	1,554bc	1,411c	28h-o	25lm	99abc	91c	2.1h-l	1.9i	77.8b	70.6b
		V_3	1,308c-g	1,188gh	29f-k	26kl	91cd	82e	2.3efg	2.1g	77.8b	70.6b
		V_4	1,279c-h	1,161ghi	30e-i	28ij	85de	78f	2.1h-l	1.9i	72.8e	66.1f
	S_2	V_1	1,405b-e	1276f	28h-o	25lm	96c	87d	2.4d-g	2.2f	73.8d	67.0e
		V_2	1,535bc	1,394cd	31d-h	29hi	97bc	88d	2.7bc	2.4d	71.5a	64.9a
		V_3	872n-v	792tu	27i-p	24mno	59k-r	54kl	3.0a	2.8a	69.3gh	62.9j
		V_4	724r-x	657xy	30e-i	28ij	50r-y	46r	2.7bc	2.4d	60.3mn	54.8p
	S_3	V_1	843n-w	827st	33d-f	32e	50r-y	49n-q	2.5cde	2.3e	73.5lm	66.8f
		V_2	744r-x	675xy	25m-t	23op	53o-x	47qr	2.7bc	2.4d	80.3f	72.9h
		V_3	1,202d-k	1,091jk	30e-i	28ij	79ef	71g	1.8o-t	1.7k	72.3e	65.7g
		V_4	987i-r	897opq	30e-i	28ij	67h-l	61i	1.6tuv	1.4n	76.3c	69.3c
	S_4	V_1	1,214d-k	1,102jk	30e-i	28ij	73fgh	66h	1.7q-u	1.5m	73.8d	67.0e
		V_2	958i-s	870qrs	34cde	31ef	54o-w	49n-q	1.8o-t	1.7k	66.6jk	60.5l
		V_3	752r-x	683wxy	28h-o	25lm	53o-x	48qr	2.1h-l	1.9i	71.7f	65.1g
		V_4	1,333b-f	1307ef	26l-s	25lm	92cd	90c	2.4d-g	2.2f	67.2ij	61.1k
WR_3	S_1	V_1	699s-x	588yz	28h-o	24mno	47t-y	49n-q	1.9m-r	1.6l	58.1op	47.2w
		V_2	940j-s	405z	28h-o	19rs	59k-r	39t	2.0k-p	1.3o	56.9qr	50.6t
		V_3	1,217d-j	796tu	29f-k	20qr	66h-n	47qr	2.0k-p	1.6l	56.7qr	51.2s
		V_4	946j-t	464z	21u-x	16t	72fgh	52lm	1.7q-u	1.4n	54.7s	43.2y

Table 10. Continued.

WR_3	S_2	V_1	680s-x	508yz	21u-x	20qr	55n-v	47qr	2.2e-h	1.5m	58.1op	48.4v
		V_2	855n-w	437z	21u-x	18s	64h-n	43s	2.2e-h	1.7k	52.6u	44.6x
		V_3	1,120f-n	749uv	25m-t	30fgh	64h-n	43s	2.2e-h	1.6l	57.1pq	47.8w
		V_4	870n-v	1,142hij	22s-w	27jk	64h-n	65h	2.4d-g	2.1g	57.7pq	54.0p
	S_3	V_1	870n-v	1,134ijk	29f-k	36c	48s-y	51mn	2.0k-p	1.4n	53.0t	54.4p
		V_2	935k-u	1006l	29f-k	30fgh	52p-y	56j	1.9m-r	1.6l	60.4mn	56.1o
		V_3	1,035g-q	652yz	32d-g	25lm	55n-v	39t	2.0k-p	2.0h	55.5rs	43.2y
		V_4	782o-x	709vwx	22s-w	24mno	60j-q	42s	1.9m-r	1.8j	59.3no	60.9l
	S_4	V_1	756r-x	892pqr	22s-w	23op	55n-v	56j	1.9m-r	1.7k	51.6v	47.8w
		V_2	558x	618z	18wx	19rs	46u-y	47qr	2.0k-p	1.6l	56.0qs	48.8v
		V_3	7,86o-x	1,134ijk	22s-w	35cd	53o-x	49n-q	1.9m-r	1.4n	55.3rs	51.2s
		V_4	1,165e-m	1,273f	28h-o	32e	72fgh	65h	2.0k-p	1.3o	56.9qr	52.7r
WR_4	S_1	V_1	1,047g-o	1,083k	21u-x	27jk	69f-j	7/60i	1.6tuv	1.6l	52.3u	52.0r
		V_2	1,037g-p	884pqr	22s-w	26kl	65h-n	52lm	1.7q-u	2.2f	54.3s	51.2s
		V_3	892m-v	799tu	24o-u	30fgh	57m-t	43s	1.8o-t	2.2f	53.6t	49.2u
		V_4	789o-x	539yz	21u-x	18s	53o-x	39t	1.5uv5	1.6l	55.5rs	61.6k
	S_2	V_1	916l-v	734vw	23q-w	28ij	59k-r	42s	1.9m-r	2.1g	53.2t	53.5q
		V_2	893m-v	487z	20vwx	16t	60j-q	43s	1.7q-u	1.2p	52.6u	54.9p
		V_3	736r-x	947mno	23q-v	31ef	44xyz	48qr	2.0k-p	1.6l	48.0y	44.6x
		V_4	726r-x	1,123ijk	24o-u	27jk	46v-y	65h	1.9m-r	1.8j	45.6qr	50.0t
	S_3	V_1	1,186d-l	861qrs	24o-u	26kl	67h-l	49m-q	1.7q-u	1.5m	52.5u	51.9s
		V_2	658u-x	898opq	21u-x	27jk	42yz	50n-q	1.8o-t	1.6l	55.4r	51.0s
		V_3	803o-x	685wxy	23q-v	25lm	52p-y	42s	1.6tuv	2.2f	50.7w	48.3v
		V_4	659u-x	562yz	21u-x	18s	45w-z	39t	1.4vw	1.9i	54.9s	54.9p
	S_4	V_1	758q-x	538yz	23q-v	24mno	47t-y	38t	1.2w	1.2p	51.6v	49.0u
		V_2	653vwx	585yz	28h-o	34d	36z	30u	1.4vw	1.6l	49.2x	51.7s
		V_3	694s-x	990lm	22s-w	27jk	44xyz	56j	1.6tuv	1.8j	50.9w	49.7u
		V_4	785o-x	936nop	27i-p	21q	56n-u	65h	1.8o-t	1.8j	49.7x	52.3r

of 1 dS m^{-1} in 2015 and 2016 were 73 and 63, respectively (Table 5). The numbers of pods in 2015 and 2016 in treatment of 80% water requirement and salinity level of 1 dS m^{-1} were 94 and 86, respectively (Table 6). The numbers of pods in 2015 and 2016 in Guil cultivar were 66 and 67, respectively, and 67 and 68 in Jonobi cultivar, respectively (Table 7). The maximum numbers of pods in treatment of 80% water requirements and cultivar Guil in 2015 and 2016 were 94 and 86, respectively (Table 8). The number of pods in salinity of 1 dS m^{-1} in 2015 in the Mesri cultivar was 77, and it was 69 in Guil cultivar in 2016 (Table 9). The numbers of pods in the cultivar Guil and treatment of 100% water requirement and salinity level of 1 dS m^{-1} in 2015 and 2016 were 107 and 97, respectively (Table 10). By increasing water stress and salinity, the numbers of pods decreased, since by increasing the osmotic potential in the root zone, water absorption by root decreased [18]. In this situation, due to the loss of pegs and lack of pod formation as well as global warming and stiffness of soil, the peg is not completely formed. In addition, the flowering stage compared to the vegetative growth stage is more sensitive to water stress and salinity, and the effect of high salinity stress on a reduced number of pods is more than water stress effect [8].

Seed Length

The effects of irrigation; salinity; the interaction of irrigation and salinity; the interaction of salinity and cultivars; combined irrigation, salinity, and cultivars; and irrigation and cultivars are significant (Table 4). See lengths in 100% water requirement in 2015 and

Table 11. Production function based on peanut cultivars, water use, and salinity on seed yield.

2015	2016
Y_{Guil}=1,181.065-0.388wu-22.166s	Y_{Guil}=954.465-0.0003397wu-5.026s
Y_{Gorgni}=1,340.383-0.006wu-94.155s	Y_{Gorgni}=1,061.916-0.0005901wu-50.88s
Y_{Jonobi}=1,335.9-0.006wu-76.302s	Y_{Jonobi}=1,110.56-0.002wu-34.943s
Y_{Mesri}=949.763-0.008wu-4.029s	Y_{Mesri}=817.97-0.002wu-23.401s

Y: Seed yield (kg ha^{-1}), WU: Water use (mm). S: Salinity (dS m^{-1}).

2016 were 2.4 and 2.1 cm, respectively (Table 5). Seed lengths in 2015 and 2016 in salinity of 3 dS m^{-1} were 2.4 and 2.1 cm, respectively (Table 5). In reaction of water requirement and salinity treatments in 2015 and 2016, the maximum length in 80% water requirement and salinity of 3 dS m^{-1} was 2.8 and 2.7 cm (Table 6). Seed length in 2015 in Guil and Gorgani cultivars was 2.1 cm and in 2016 was 2 cm (Table 7). In 100% water requirement and in Guil, Gorgani, Mesri, and Jonobi cultivars, the lengths of seeds in 2016 were equal (2.4 cm) (Table 8). In salinity of 3 dS m^{-1} in 2015 in Jonobi cultivar and in 2016 in Mesri cultivar, seed lengths were 2.5 and 2.3 cm, respectively (Table 9). Seed length in 2015 in 80% water requirement with salinity of 3 dS m^{-1} was 3 cm in Jonobi cultivar. In 2016, maximum seed length was 2.8 cm at the salinity level of 3 dS m^{-1}, which is related to Guil, Jonobi, and Mesri cultivars in 100% water requirement conditions, and Jonobi cultivar in treatment of 80% water requirement (Table 10). It has been reported that salinity, by increasing the osmotic pressure of soil solution, leads to reduced water absorption and decreased cell differentiation, and thus reduced seed length [18].

Plant Height

The effect of irrigation on plant height was significant in 2015 and 2016 at probability level of 5%. Salinity values; the interaction effect of irrigation and cultivars; the combined effects of irrigation, salinity, and cultivars; and the interaction of salinity and cultivars on plant height were significant in 2015 and 2016 at probability level of 1% (Table 4). The highest plant height in 80% water requirement in 2015 and 2016 was 72.4 and 65.7, respectively (Table 5). The highest plant height at salinity of 1 and 5 dS m^{-1} in 2015 and 2016 obtained 63.4 and 59.5 cm, respectively (Table 5). Maximum plant heights in 2015 and 2016 in treatment of 80% water requirement and salinity of 1 and 5 dS m^{-1} were 75.6 and 68.7 cm, and 75.3 and 68.4 cm, respectively (Table 6). Gorgani cultivar in 2015 had the highest plant height (62.5 cm) (Table 7). Maximum plant heights in 2015 and 2016 were in treatment of 80% water requirement and in Gorgani cultivar with 74 and 67.2 cm, respectively (Table 8). Gorgani cultivar with salinity tolerance of 3 dS m^{-1} in 2015 and 2016 had maximum heights of 66.5 and 62.1 cm, respectively (Table 9). Maximum plant heights in the combined effect of irrigation, salinity, and cultivars in 80% water requirement and with salinity of 3 dS m^{-1} were seen in Gorgani cultivar in 2015 and 2016 at 71.5 and 64.9 cm, respectively (Table 10). Research demonstrated that a shortage of water by reducing the plant growth rate reduces the height of the plant and increases salinity up to 3 dS m^{-1}, which is directly associated with reduced height, which is consistent with the results of this study [18].

Estimate of Production Function

The relationship between the value of water used and salinity levels and yield in peanut cultivars is shown in Table 11. With increasing salinity level, yield level decreased significantly and the salinity level of 7 dS m^{-1}, and the highest yield decline was seen in the cultivars. In the regard, the most sensitive cultivar to salinity was Mesri and the most tolerant was Jonobi.

Conclusions

According to the results of this study, tolerance of peanut cultivars to salinity varied. The highest seed yields in 80% of water demand management in 2015 and 2016 were, respectively, 1,177 and 1,169 kg ha^{-1}. The highest seed yields in salinity levels in terms of 1 dS m^{-1} in 2015 and 2016 were, respectively, 1,142 and 978 kg ha^{-1}. In the interaction between irrigation and salinity levels, the highest seed yield in 80% of water and salinity 1 dS m^{-1} in 2015 and 2016 was, respectively, 1,393 and 1,265 kg ha^{-1}. The maximum seed yield was in Jonobi cultivar with 1 dS m^{-1} in salinity and Guil cultivar with 5 dS m^{-1} in salinity, respectively, at 1,254 and 1,127 kg ha^{-1}. Guil cultivar in terms of 100% water requirement and with salinity 1 dS m^{-1} in 2015 and 2016, respectively, in 1,883 and 1,710 kg ha^{-1} had the highest seed yield. Thus, the Guil cultivar is the most suitable cultivar for cultivation in the region.

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