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Effects of Yield and Physiological Indexes on Screening Different High-Oleic Acid Peanut Varieties and Lines under Saline-Alkali Stress

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Abstract

Nearly two-third of the world's cultivated land belongs to saline-alkali type having very little agricultural impact. Peanut (*Arachis hypogea* L.) can be a promising crop to cultivate in this type of soils in the People's Republic of China. Peanut is a suitable crop to grow in neutral acid soils but salt alkali stress affects peanuts production. However, it has been seen that different peanut varieties show different salt stress tolerances. In the present investigation, distinct peanut varieties differing in salt tolerance were initially identified from two separate experiments using two systems. The first screening involved two diverse groups of 27 high oleic acid peanut entries. The yield was determined to screen the cultivars for differences in salt tolerance of field test for 2016 and 2017 in the first experiment. A set of four varieties (three tolerant and one susceptible) were selected from this experiment against Fuhua 12 (normal oleic) as a control. The varieties were then subjected again to salt stress adopting pot culture system in the second experiment being involved in a screening approach on yield, yield-related traits and physiological indexes. The results suggested that: Huayu 967 and Huayu 669 were medium tolerant, 16L2 low tolerant, 16S5, Fuhua 12 susceptible. For the field test, more than 2950.05 kg/ha of pod yield can be selected as salt-tolerant varieties. Compared with the susceptible entries, the advantages of medium tolerant entries were grouped as follows. The first group was screened on the basis of the relative values of the numbers of pods, branches with pods and total pods which were higher than 60%. In it the salt tolerant index (STI) and economic yield were also high and was not less than 66%. The second group had the net photosynthetic rate values of medium tolerant entries under salt-alkali stress which were both higher than the normal soil. In this group the chlorophyll content of Huayu 967 was higher than other entries in each growth period. The final and the third group had been characterized as the malondialdehyde concentration of medium tolerant peanut increased little under salt-alkali stress.

Keywords: High oleic acid peanut; Saline-alkali stress; Yield; Physiological indicators; Screening peanut strains

Introduction

More than 955 million hectares of saline-alkali land are distributed all over the world. It accounts 2/3rd of the total cultivated lands, and its area has still been increasing (Lin *et al.* 2012). Global annual population increase, coupled with decreasing arable land and a growing condition of food crisis has attracted more and more attention to the development and utilization of salinized land (Guo *et al.* 2015). Soil salinization occurs due to excessive accumulation of salinity, which causes severe water loss to crops. So, saline soils not only reduce the biological and economic yield of crops strongly, but also poses a severe impact on product quality (Guo *et al.* 2015). Introduction of new varieties of salt-tolerant crops in those areas and to bring the crops under cultivation appears to be the most economical and effective way to overcome the problem (Xu *et al.* 2019).

Peanut (*Arachis hypogea* L., Fam.: Fabaceae) is an important oil crop in the People's Republic of China and the crop is suitable for growing in neutral acid soil (Xu *et al.* 2019). However, salt-alkali stress affects peanut yield. Previous studies have shown that different peanut varieties have different salt stress tolerance. It has been seen that with the increase of salt concentration, plant growth rate, plant water content, leaf water potential, photosynthetic pigments, total carbohydrates and other traits all decreased significantly (Hammad *et al.* 2010). Peanut with high oleic

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acid content refers to peanut varieties with the oleic acid content of 75% or more of the total fatty acids (Moore and Knauft 1989). It has a strong antioxidant capacity, beneficial to human health, good storage durability, and the shelf life of processed food is significantly prolonged. As a result, the market prospects are optimistic. Therefore, if it is possible to cultivate saline-alkali-tolerant peanut varieties with high oleic acid content, it will be of great significance for the development of peanut production. The cultivation prospect would then expand the peanut planting area, increase farmers' income ensuring the safety of edible oil. In recent years, considerable information on the mechanism of salt tolerance of ordinary peanuts has been obtained. Tolerance to salinity stress in peanut is conferred by a higher allocation of assimilation capacity to the kernel through maintaining total sugar and chlorophyll-a contents close to unstressed treatment (Mohammad *et al.* 2012). The salt sensitivity of peanut is the sum of the effect of rooting zone NaCl on biomass and the effect of pegging zone NaCl on seed development (Smitharani *et al.* 2014). WRKY and Na+/H+ genes might be responsible for imparting tolerance to salinity stress in peanut (Bera *et al.* 2013). But the information on high oleic acid peanut varieties was not available, just on the production and quality of high oleic acid peanuts under salt and alkali stress ((Su *et al.* 2017; Su *et al.* 2018; Xu *et al.* 2019). For the first time and through a two-year field salt-tolerance stress study, Wang put forwarded the identification standard of salt-tolerance of high-oleic peanuts based on relative yield (Su *et al.* 2017). Chi Xiaoyuan found different levels of reduction on the oil content, oleic acid content, oil sub-proportion of high-oleic acid peanut varieties (lines) planted in saline-alkali land (Xu *et al.* 2019). In the present experiment, four high-oleic acid varieties (lines) with different responses to saline-alkali obtained through a two-year field salt-alkali stress test were screened. For the first time, the physiological indexes of saline-alkaline combined with yield and yield-related traits to discuss the resistance mechanism of high-oleic peanut varieties, which will provide a reference for the future selection of salt-tolerant for high-oleic peanut varieties.

Materials and Methods

Experiment 1

The field test was carried out between 2016 and 2017 in Baicheng Jilin Province (122.83° E 45.62 °N) which includes saline-alkali and cinnamon soil. The experimental materials were 27 high oleic acid varieties (lines) of peanuts which were collected from Shandong Peanut Research Institute. The test plots were uncultivated fallow saline-alkali land with vegetation cover mainly by reeds and alkali grasses. After de-weeding and ploughing the land the plots were made ready for plantation. The divided zone did contain one ridge (2.0 × 0.6 m) per zone and 1 row per ridge. Each row has 25 holes, and each hole was sown with 1 capsule of peanut. Both the small and the large peanut groups were designed with random blocks and 4 replicates (the yield data was calculated after combining 4 replicates). The peanut lines were planted on May 27 and the crops were harvested on September 29.

Experiment 2

Materials: The materials were 4 high oleic acid varieties (lines) that were selected from the Experiment 1, after two years of field salt-alkali stress tests. The peanut varieties (lines) were: Small 16S5, Huayu 669 and large Huayu 967, 16L2. The control variety was Fuhua 12. Huayu 669 and Huayu 967 performed best in experiment one, 16S5 and 16L2 performed the worst. Fuhua 12 is the main local variety.
Test design: The experiment was carried out in pot planting and for which two kinds of soils were used. These are saline-alkali soil and cinnamon soil (control), the former soil was collected from the uncultivated saline-alkali land spot in Baicheng (Jilin province) and the latter soil category was collected from 0–30 cm surface soil (cinnamon soil) in peanut breeding field in Fuxin (Liaoning Province). The cinnamon soil had a salt content of 0.114% and a pH of 6.5. On the other hand, the total salt content of saline-alkali soil was 0.241% having a pH value as high as 10.1. Each variety of the two types of soil was set up with 3 replicates, each containing 2 pots and 6 seedlings per pot following a random block design.
Methods: The pot culture experiment was conducted in the dry shed of the peanut breeding test base (Fuxin) of the Institute of Sandy Land Management and Utilization of Liaoning from 29 May to 9 October 2017. The pot used for the experiment was 21 cm high with an outer diameter of 35 cm. The saline-alkali soil was transported from the salt-alkali field of Experiment 1. After mixing, stirring, and sieving the test soil was made ready for carrying out the experiment. Each experimental pot was filled with 20 kg of soil. Ten peanut seeds were sown in each pot and when the seedling grew, 6 seedlings were kept for running the experiment by removing the others. Watering to the test pots was done at every 7–10 days according to the soil moisture. The volume of water in each pot was the same and when the temperature in the shed is high, the shading net was used. Ten peanut plants with uniform growth were selected during the harvest of the cinnamon soil, and all plants in the saline-alkali soil were harvested following the measurement of their yield and yield-related traits.

The economic yield was the dry weight yield of the pods per plant but the biological yield was determined by the drying method. The samples were washed with water and then dried with filter paper. Different organs of the experimental peanut plants such as roots, stems and petioles, leaves and pods were separated and dried in an oven at 105℃ for 30 min and then dried to a constant weight at 70℃ (Tian *et al.* 2019).
Relative yield: The relative yield was calculated following

the formula: Relative yield = yield under stress/yield of the variety under non-stress × 100%. The grading standard for peanut salt-tolerant identification was done via relative yield determination as mentioned above. The scales were: relative yield> 85% is high tolerance, 60%<relative yield≤85% is medium tolerance, 45%<relative yield≤60% is low tolerance and relative yield≤45% is susceptible (Su *et al.* 2018).

Photosynthetic index: It was measured on the functional leaves (the main stem inverted three leaves) at the flowering stage of the experimental plants. A sunny day without wind was selected for the measurement, and the data on photosynthesis was recorded with the help of a LI-6400 photosynthesis instrument (LI-COR of American), repeating 5 times for each plant.

Chlorophyll determination: The chlorophyll concentration (relative amount of chlorophyll at two wavelengths) was estimated by measuring soil plant analysis development (SPAD) values. The SPAD-502 Plus chlorophyll meter of Nissan was used to determine the SPAD value of peanut functional leaves on 20 July, 25 August, and 27 September 2017, and the measurement was repeated for 5 times.

Chlorophyll stability index: Chlorophyll Stability to salt stress was assessed after Seydi *et al.* (2007). The Chlorophyll Stability Index (CSI) was modified as the percentage of chlorophyll of the salt-stressed sample relative to its content in the control sample as follows:

$$CSI=\frac{Content of chlorophyll is alt stressed sample}{Content of chlorophyl1 in control sample} \times 100$$

Salt tolerance index (STI): To determine this parameter, the procedure of Seydi *et al.* (2007) was adopted using the following formula:

$$STI=\frac{Tatal dry weight of salt stressed plant}{Tatal dry weight of salts control plant} \times 100$$

Malondialdehyde (MAD) determination: The functional leaves of peanuts were sampled at plump pods mature stage, quickly placed in liquid nitrogen, and measured by Soluble Bao Malondialdehyde (MDA) content detection kit (BC0025). At each treatment of each variety (system) the data measurement was repeated for 3 times.

Relative value calculation:

$$Relative\ value = \frac{the value under saline-alkali stress}{the value under control soil} \times 100$$

Data Analysis

DPS 7.05 software was used for data collation and analysis, and multiple comparisons were used for the analysis of variance.

Results

Yield of field test for 2016 and 2017 in Baicheng

From Table 1, pod yield ranged from 1000.05 to 5208.00 kg/ha and the kernel yield ranged from 709.95 to 3249.75 kg/ha. Huayu669 had the highest yield in small peanut group having pod yield 2950.05 kg/ha, kernel yield 2032.50 kg/ha and surviving plants 19.00. The values were higher than the varieties (lines). Huayu967 had the highest yield in big peanut group having pod yield 5208.00 kg/ha, kernel yield 3249.75 kg/ha and surviving plants 21.00, all of which were higher than ten varieties (lines).

Based on the information presented in Table 2–3 and according to the principle of low, the tolerant performances by different varieties were Huayu 669 medium, Huayu 967 high and 16S5 low and 16L2 performed as susceptible.

Yield and yield-related indicators of pot culture

Number of surviving plants: There should be 36 plants of each entry at last, with the prolongation of salt-alkali stress, some plants gradually died. The plants of Huayu669 were more survivable than other varieties during the whole growing period (Table 4). Huayu967 ranked second but in 16L2 and 16S5 and Fuhua12 many plants died before 3 August 2017. After growing for 89 days and on 25 August 2017 there were no more plants died for Huayu967.

Economic and biological yields of different varieties during mature period under salt-alkali stress: Table 5 showed the relative value of yield and yield-related indices for all the tested varieties. It is seen that Huayu 967 and Huayu 669 occupied in the top two for each index. On the other hand, 16L2, 16S5, Fuhua 12 ranked 3rd, 4th and 5th positions, respectively. According to the grading standard of peanut salt-tolerant identification, Huayu 967 and Huayu 669 showed medium tolerant, 16L2 was low tolerant, and 16S5 and Fuhua 12 were susceptible (Table 5).

Comparison of yield-related traits of various varieties under saline-alkali stress: From Table 6, the relative values of yield-related traits have decreased in different degrees under salt-alkali stress. Each index of Huayu 967 and Huayu 669 ranged from 62–90% and 60–98%, respectively and could be said that the indices were mostly higher than 60%. The relative values of total branches, fruiting branches and total pods for Huayu 669 reached more than 90%, with the smallest decrease. However, the relative values of plump pods for Huayu 669 and Huayu 967 were 63 and 64%, respectively which is higher than other varieties.

Comparison of physiological indexes of various varieties under salt-alkali stress of pot culture

Comparison of net photosynthetic rate during flowering stage: From Fig. 1, under saline-alkali stress, the net photosynthetic rate of all varieties (lines) was less than 10 μmol·CO_2·m^{-2}·s^{-1}, and the order was: Huayu669 > Huayu967 > 16L2 > Fuhua12 > 16S5. The two medium tolerant varieties of Huayu 669 and Huayu 967 showed up to 5.29 and 4.91 μmol·CO_2·m^{-2}·s^{-1}, respectively and the

Table 1: Surviving plants and yield of small peanut and large peanut (second column) varieties (lines) in 2016

Varieties (lines)	Plants per block	Pod yield (kg/ha)	Kernel yield (kg/ha)	Varieties (lines)	Plants per block	Pod yield (kg/ha)	Kernel yield (kg/ha)
15S1	13.30abc	2179.05	1420.65	15L1	14.00AB	1954.05	1238.85
15S3	8.70c	1303.95	925.80	Huayu967	21.00A	5208.00	3249.75
15S8	15.00abc	1546.05	1066.80	16L2	5.30B	1000.05	709.95
15S9	11.00c	1429.05	951.75	15L4	8.70B	1195.95	819.30
16S5	9.70c	1333.05	867.75	15L8	11.70B	1828.95	1130.25
15S13	15.00abc	1378.95	1031.55	15L9	10.30B	1458.00	1073.10
15S24	20.30a	2688.00	1771.35	15L10	1.00B	1945.95	1224.00
Huayu669	19.00ab	2950.05	2032.50	15L11	14.00AB	1683.00	1031.70
15S28	13.30abc	1624.95	1078.95	15L15	11.00B	1699.95	1099.95
Huayu20	11.70bc	1467.00	971.10	15L16	10.30B	1741.95	1263.00
Baiyuanhua 1	15.70abc	1513.05	1099.95	15L17	10.70B	1738.05	1070.55
Baiyuanhua 2	16.70abc	1458.00	1032.30	15L18	9.30B	1483.05	909.15
				Huayu33	8.00B	1413.00	897.30

Note: Lower case letter represents significance at 0.05, uppercase letter represents probability level significance at 0.01

Table 2: Yield performance of pods and kernels for 2016 and 2017 (kg ha^{-1})

varieties (lines)	2017 Saline-alkali soil		2017 Cinnamon soil		2016 Saline-alkali soil		2016 Cinnamon soil		Relative yield of pod (%)		Relative yield of kernel (%)	
	Pod yield	Kernel yield	Pod yield	Kernel yield	Pod yield	Kernel yield	Pod yield	Kernel yield	2017	2016	2017	2016
Huyu669	2783.40AB	2076.45AB	4073.25bc	3091.40	2950.05	2032.50	4315.95	3185.25	68.33	68.35	67.17	63.81
Huyu967	3083.40AB	2301.90AB	3600.00bc	2678.40	5208.00	3249.75	4288.05	3126.00	85.65	121.45	85.94	103.96
16S5	1528.76ABC	1091.78ABC	2980.05c	2246.90	1333.05	867.75	2662.95	1927.95	51.3	50.06	48.61	45.01
16L2	1833.30ABC	1370.10ABC	3939.90bc	2892.00	1000.05	709.95	2737.95	2050.80	46.53	36.53	47.38	34.62

Note: Lower case letter represents significance at 0.05, uppercase letter represents probability level significance at 0.01

Table 3: Judging tolerance based on relative yield

Varieties (lines)	According to the relative yield of pod		According to the relative yield of kernel		According to the principle of low
	2017	2016	2017	2016	
Huayu 669	medium tolerant	medium tolerant	medium tolerant	medium tolerant	medium tolerant
Huayu 967	high tolerant	high tolerant	high tolerant	high tolerant	high tolerant
16S5	low tolerant	low tolerant	low tolerant	low tolerant	low tolerant
16L2	low tolerant	susceptible	low tolerant	susceptible	susceptible

Table 4: Number of surviving plants

	July 20	August 3	August 19	August 25	September 11	October 9
Huayu 967	22	18	17	14	14	14
16L2	19	14	12	9	8	6
16S5	21	14	11	8	5	5
Huayu 669	28	27	26	26	26	19
Fuhua12	11	8	8	8	7	7

Table 5: Relative value of yield and yield-related indicators of each entry under saline-alkali stress (%)

	Root dry weight	Stem dry weight	Leaf dry weight	Salt tolerance index	Economic yield
Fuhua12	47	37	43	41	32
Huayu 967	93	71	82	78	80
16L2	66	53	55	55	46
16S5	62	51	57	50	35
Huayu 669	96	62	67	66	70

values were larger than the normal cinnamon *i.e.*, 3.98 and 4.54 $\mu mol \cdot CO_2 \cdot m^{-2} \cdot s^{-1}$, respectively. The net photosynthetic rate of other three varieties (lines) under saline-alkali soil was lower than that of cinnamon soil. The smallest was recorded for Fuhua12 (3.02 $\mu mol \cdot CO_2 \cdot m^{-2} \cdot s^{-1}$) which is 1.41 $\mu mol \cdot CO_2 \cdot m^{-2} \cdot s^{-1}$ lower than the value of normal cinnamon soil and the percentage of decrease was 31.9%.

SPAD values of various varieties (lines) at different growth stages: SPAD value correlated positively with the chlorophyll content in the leaf. The SPAD value of the leaf reflects the level of the chlorophyll content. Table 7 showed CSI of all varieties in the three periods (the flowering, the poding and the plump pod mature stage) were consistent. As shown in Fig. 2, under salt-alkali stress, the highest chlorophyll content in each period was recorded for Huayu 967, which were 37.75, 44.47 and 41.7 for 3 stages,

Table 6: Relative value of yield-related traits (%)

	Main stem height	Lateral branch length	Total branches	Fruiting branches	Total pods	Plump pods
Fuhua12	53	49	69	63	56	37
Huayu 967	90	62	73	81	75	64
16L2	81	45	71	85	61	59
16S5	56	47	72	74	71	48
Huayu 669	62	60	98	98	94	63

Table 7: CSI of each entry during different growth periods (%)

	Flowering stage	Poding stage	Plump pods mature stage
Fuhua12	72	74	73
Huayu 967	85	89	96
16L2	75	77	82
16S5	59	65	66
Huayu 669	75	83	86

Table 8: MAD Content of the third leaf from top during maturing period (nmol g^{-1})

	Fuhua12	Huayu967	16L2	16S5	Huayu669
Saline-alkali soil	55.69	41.81	640	36.65	49.71
cinnamon soil	52.25	34.40	23.60	25.67	48.93
relative value	1.07	1.22	2.56	1.43	1.02

Table 9: Correlation analysis of yield, agronomic trait and physiological indicators under saline-alk ali stress

	Fresh pod weight per plant	Dry pod weight per plant	Dry root weight per plant	Dry stem weight per plant	Dry leaf dry weight	Biological yield	Main stem height	Lateral branch length	Total No. of branches	Fruiting branches	Total pods	Plump pods	Photosynthetic rate	SPAD	MDA
Dry pod weight per plant	0.72														
Dry root weight per plant	-0.62	-0.11													
Dry stem weight per plant	-0.14	-0.38	0.33												
Dry leaf dry weight	0.07	-0.48	-0.07	0.88*											
Biological yield	-0.07	-0.45	0.18	0.97**	0.96**										
Main stem height	-0.06	-0.03	0.21	0.75	0.49	0.63									
Lateral branch length	0.03	-0.09	-0.003	0.73	0.57	0.65	0.98**								
Total No. of branches	0.66	0.15	-0.99**	-0.36	0.06	-0.19	-0.29	-0.09							
Fruiting branches	0.91*	0.50	-0.73	-0.30	0.05	-0.15	-0.40	-0.28	0.80						
Total pods	0.73	0.61	-0.71	-0.76	-0.48	-0.66	-0.60	-0.50	0.76	0.83					
Plump pods	0.88	0.50	-0.79	-0.44	-0.07	-0.29	-0.47	-0.34	0.88	0.99**	0.90*				
Photosynthetic rate	0.73	0.15	-0.96**	-0.23	0.20	-0.05	-0.25	-0.05	0.98**	0.86	0.72	0.89*			
SPAD	0.81	0.20	-0.83	-0.09	0.33	0.93	-0.27	-0.10	0.88*	0.93*	0.67	0.91*	0.95*		
MDA	0.20	0.06	-0.09	0.67	0.53	0.60	0.95*	0.98**	0.01	-0.12	-0.36	-0.19	0.05	0.02	
Oleic acid content	0.71	0.73	-0.59	-0.8	-0.6	-0.74	-0.57	-0.5	0.62	0.76	0.98**	0.83	0.57	0.53	-0.37

Note: * significance at 0.05, ** probability level significance at 0.01

respectively. Followed by Huayu669 and 16L2, the smallest were Fuhua 12 and 16S5, the chlorophyll content of 16S5 was only 38 at the flowering stage. The CSI of Huayu 967, Huayu 669, 16L2 in each period were greater than 75%, and the susceptible varieties (lines) were between 55 and 74%.

Comparison of malondialdehyde content of various varieties (lines) under salt-alkali stress: It can be seen from Table 8 that under saline-alkali stress, the malondialdehyde concentration of all the varieties (lines) was higher than the value of cinnamon soil. The line 16S5 had the lowest malondialdehyde concentration under saline-alkali stress, followed by Huayu 967, Huayu 669 and 16L2 had the highest malondialdehyde content. The relative values of Huayu 669, Fuhua 12, Huayu 967 were low, and the concentration of malondialdehyde increased by 78, 44 and 7.4 nmol g^{-1}, respectively under saline-alkali stress. However, 16L2 and 16S5 increased much more, reaching 36.77 and 198 nmol g^{-1}, respectively.

Correlation analysis of various indicators

Table 9 showing the biological yield under salt-alkali stress is extremely positively correlated with stem and leaf dry weight per plant. The height of the main stem was significantly correlated with the length of lateral branches. Oleic acid content was significantly positively correlated with the total pods. Poding branches correlated significantly and positively with the fresh weight of pods per plant (Lauter and Meiri 1990), and highly significantly positive correlation was shown with the number of plump pods. The net photosynthetic rate correlated positively and the level of significance was high with the total number of branches and the number of plump pods. There was a significant positive correlation between the concentrations of malondialdehyde some biological traits. The concentration of malondialdehyde was significantly positively correlated with the height of the main stem and the length of the lateral branches, respectively.

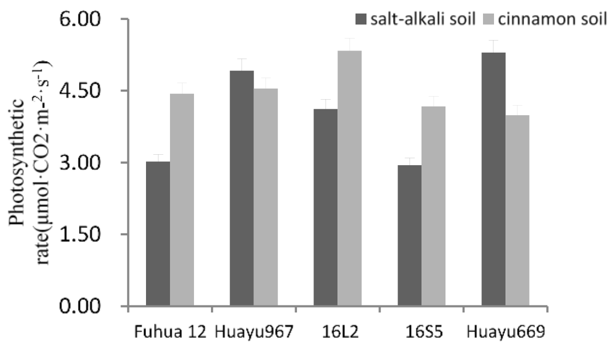

Fig. 1: Photosynthetic rate of each entry during flowering period

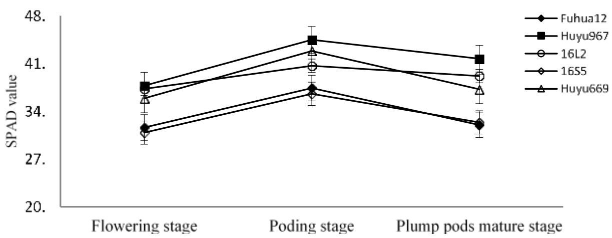

Fig. 2: SPAD value of each entry during different growth and development periods under saline-alkali stress

Discussion

The seed yield of 210 high yielding peanut germplasm accessions, under saline condition, ranged from 0 to 2030 kg ha^{-1} (Singh *et al.* 2016). In the present investigation, the kernel yields ranged from 867.75 to 3249.75 kg ha^{-1}. The yield per plant of Huayu 25 under non-saline soil was 12.69 ± 1.32a (g) and under saline-alkaline soil the value was 4.48 ± 0.38c (Tian *et al.* 2019), wherein the STI value was 35%. This had shown no big difference with susceptible varieties but lower than the salt-tolerant varieties of experiment 2 (Huayu 967 and Huayu 669). So, it is understood that the salt-tolerant varieties (lines) in this research performed well.

According to the grading standard of peanut salt-tolerant identification, the high-oleic acid peanut varieties (lines) selected in Experiment 2 under pot salt-alkali stress showed the salt-tolerant ability as follows: Huayu 967 and Huayu 669 were medium tolerant, 16L2 low tolerant, 16S5 and Fuhua 12 susceptible. Compared with the same varieties (lines) in the field, the tolerance of Huayu 669 remained unchanged but Huayu 967 decreased from high tolerance to medium tolerance and 16S5 decreased from low tolerance to susceptible. It could be speculated that it may be because the saline-alkali soil used for pot experiment was the salt spot in the saline-alkali plot, and the intensity of saline-alkali stress was greater than the field experiment.

Previous studies showed that the saline-alkali stress significantly inhibited the growth and development of peanut plants, where the main stem height, lateral branch length was significantly reduced (Zhang *et al.* 2016). Main stem height, lateral branch length, and yield are used as indicators to evaluate peanut salt-tolerance, and the total number of branches needs to be studied further (Wang *et al.* 2013). In experiment 2, Huayu 967 and Huayu 669, which had more tolerance, also showed reduction in main stem and lateral branch, but less than the intolerant varieties. The relative value of fruiting branch number of the susceptible varieties was as low as 63%, while they were as high as 81 and 98% of Huayu 967 and Huayu 669. And the fruiting branch number under salt-alkali stress was significantly positively correlated with the yield per plant, a very significant positive correlation with the plump pods.

Salt-alkali stress can destroy the order and structure of thylakoids in the chloroplast (Zheng and Zhang 1998). The chlorophyll content in the leaves of Huayu 967, was higher than other varieties (lines) at various growth stages. The CSI of medium-tolerant and low-tolerant varieties (lines) in each period was greater than 75%. So, CSI can be used as an indicator for the high oleic acid peanut regarding salt tolerance. The net photosynthetic rate of Huayu 669 and Huayu 967 did not decrease under salt-alkali stress but had a certain promotion effect, which was consistent with previous studies (Ren *et al.* 2017). But a 31.9% reduction of photosynthetic rate took place in susceptible variety Fuhua 12. Correlation analysis showed that the net photosynthetic rate under salt-alkali stress correlated strongly, significantly and positively with the total number of branches and plump pods. The chlorophyll content was significantly positively correlated with the total number of branches, the number of fruiting branches, plump pods and the net photosynthetic rate.

When plants are exposed to salt-alkali stress for a long time, the plant membrane system gets destroyed, resulting an increase in the malondialdehyde concentration. This increase affects and destroys the normal metabolism of cells, inhibiting plant growth and even withered to death (Qiao *et al.* 2013). The concentration of malondialdehyde can reflect the degree of plant senescence and suffer from the adversity. Under salt stress, the leaves and roots of salt-alkali tolerant varieties have lower malondialdehyde concentration (Qiao *et al.* 2013). In Experiment 2, Huayu 967 had a lower malondialdehyde concentration and less increase under salt-alkali stress, which confirmed its higher salt-alkali tolerance.

Results of this study revealed that compared with non-saline-alkali stress, varieties with strong saline-alkali tolerance (Huayu 669 and Huayu 967) can reduce the main stem height and lateral branch length from the morphological point of view. These changes in the crop maintain more fruiting branches. From the physiological and biochemical point of view, less chlorophyll was destroyed, and the net photosynthetic rate did not decrease but increased. The process had helped accumulating enough organic matter and ensured a sufficient source for the source-sink fluency and economic crop output below ground.

Conclusion

Three research findings of the two best performing high-oleic acid varieties (Huayu 967 and Huayu 669) were identified: (1) from the perspective of field yield, more than 2950.05 kg ha^{-1} can be selected as salt-tolerant varieties; (2) from the morphological point of view, the relative value of main stem height, lateral branch length, total branches, fruiting branches, total pods and plump pods should be higher than 60% and (3) from the physiological and biochemical point of view, the STI was not less than 66; maintaining more chlorophyll content, the CSI should be greater than 75%; strong net photosynthetic capacity to ensure the accumulation of organic compounds and the malondialdehyde concentration should be less. So, for the selection of high oleic acid peanut saline-alkali tolerance, we could refer to the above values. Compared with the field test, pot culture has the following advantages: Firstly, the use of pot can better control the consistency of the growth environment of each test material under saline-alkali soil and cinnamon soil. The number of surviving plants can intuitively reflect the degree of tolerance, to more accurately determine the salt-tolerance of various varieties. Secondly, the pot experiment can reduce the test period and test points. The saline-alkali soil in Experiment 2 has been evenly mixed by stirring to ensure uniform salt-alkali stress and can replace the multi-point field test for many years. Next, a transcriptome analysis of four varieties will be carried out to explore the salt-tolerant genes.

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