Identification of Peanut Germplasm Tolerance to Salinity Stress

Identifikasi Toleransi Plasma Nutfah Kacang Tanah terhadap Cekaman Salinitas

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ABSTRAK

Varietas toleran salinitas adalah kunci utama pengembangan kacang tanah di tanah salin, namun sampai saat ini belum ada perakitan varietas kacang tanah di Indonesia dengan spesifikasi toleran terhadap salinitas. Penelitian ini bertujuan untuk mengevaluasi toleransi 25 aksesi kacang tanah koleksi plasma nutfah Balai Penelitian Tanaman Aneka Kacang dan Umbi terhadap cekaman salinitas untuk menyediakan sumber gen persilangan tahan salinitas. Aksesi kacang tanah ditanam pada tiga level salinitas yaitu non salin, sedang (5-6 dS/m), dan tinggi (8-10 dS/m). Parameter yang diamati meliputi skor keracunan, kadar K dan Na pada akar dan tajuk, hasil polong dan biji, dan indeks toleransi cekaman (ITC). Hasil penelitian menunjukkan bahwa semua aksesi teridentifikasi peka pada salinitas tinggi. Salinitas sedang merupakan level salinitas tertinggi yang masih dapat ditoleransi oleh 23 aksesi kacang tanah. Pada tingkat salinitas sedang, empat aksesi kacang tanah (MLGA 0211, MLGA 0222, MLGA 0546, MLGA 0570) teridentifikasi toleran, dua aksesi (MLGA 0473 danMLGA 0605) peka, dan 19 aksesi lainnya tergolong sedang. Toleransi terhadap salinitas berhubungan dengan kemampuan aksesi untuk membatasi serapan Na dan translokasinya ke tajuk sehingga rasio K/Na di tajuk tetap tinggi dan dapat meningkatkan proses fotosintesis tanaman. Rasio Na-akar/Na-tajuk sama efektifnya dengan indikator rasio K/Na tajuk, oleh karena itu dapat dijadikan kriteria baru dalam seleksi toleransi kacang tanah terhadap cekaman salinitas. Aksesi yang toleran berdasarkan kemampuan untuk membentuk polong dan biji serta kemampuan menahan efek salinitas dapat dimanfaatkan dan diintegrasikan dalam pemuliaan kacang tanah untuk toleransi salinitas.

Kata kunci: aksesi kacang tanah, rasio K/Na, salinitas

ABSTRACT

Salt-tolerant variety is the main technology for developing peanut in saline soils, however peanut breeding for salt-tolerant has not been yet conducted in Indonesia. The aim of this study was to evaluate 25 peanut germplasm accessions of Indonesian Legumes and Tuber Crops Research Institute collection for their tolerance to salinity stress in order to provide gene resources for peanut breeding. The accessions were grown at three salinity levels i.e: non saline, moderate (5-6 dS/m), and high (8-10 dS/m). Observations included the toxicity score, K and Na contents in the root and shoot, pod and seed yield, and stress tolerance index (STI). The results showed that all accessions were identified as susceptible to high salinity tolerance. The medium salinity (5-6 dS/m) was the highest level that can be tolerated by most of all peanut accessions. At such moderate–salinity, four accessions (MLGA 0211, MLGA 0222, MLGA 0546, MLGA 0570) were identified to be tolerant, two accessions (MLGA 0473 and MLGA 0605) were susceptible, and the rest of 19 accessions were moderate. The tolerance to salinity was likely related to the ability of the accessions to inhibit the Na uptake and its translocation to the shoot, resulting in high K/Na ratio in the shoot thus would increase photosynthetic process of the plants. The ratio of Na-root/Na-shoot was also an effective indicator as K/Na ratio in the shoot, therefore it can be used as a new selection criteria for peanut tolerance to salinity stress. The accessions that were identified to be tolerant based on their ability to form pods and seeds and withstand the effects of salinity can be further used and integrated in the peanut breeding for salinity tolerance.

Keywords: K/Na ratio, peanut germplasm, salinity

INTRODUCTION

Peanut is the fourth leading food crops in Indonesia after rice, maize, and soybean. The constraints of peanut production include the decrease in harvested area due to the competition with other commodities and land conversion (Sumarno 2015). The conversion of optimal agricultural land to non-agricultural land in Indonesia reaches 1% per year (Mulyani *et al.* 2016). Therefore, peanut development in future should be more focused to the suboptimal land, including saline soils.

Saline soil is a soil which contains soluble salt or their ions at least in one horizon at above the toxicity threshold with electrical conductivity (EC) of above 4 dS/m (Vargas *et al.* 2018). Salt-affected agricultural land in Indonesia was about 2,172,830 hectares or equal to 1.14% of agricultural land area (Rachman *et al.* 2013). High salinity is raising complex stresses such as osmotic water deficit, toxicity of Na and Cl, nutrient imbalance, macro nutrient defficiency, and high reactive oxygen species (ROS) that degrades macro moleculs in plant and reduces plant growth and yield (Nawaz *et al.* 2010).

Salt-tolerant cultivar is the main key for peanut cultivation in saline soils. However, peanut breeding for salinity tolerance has not been yet conducted in Indonesia. Hence, evaluation of peanut genetic resource to salinity stress is an important step to be conducted to determine resistant gene as a breeding material. Evaluation of salinity tolerance can be based on morphology, anatomy, physiology, and moleculer changes, depending on research purposes. Salwa *et al.* (2010) reported that tolerant peanut cultivar had less growth and yield, and it was more stable in its physiological and chemical components under salt stress conditions compared to less tolerant cultivar. Deshev *et al.* (2020) informed that salinity stress in early growth of peanut will decrease the energy and velocity of germination, shoot and root length, vigor index, fresh and dry weight of shoot and root. Sa *et al.* (2020) evaluated peanut genotypes based on the emergence, growth, and biomass accumulation and they reported that the tolerant genotype had high performance in germination and allocation of shoot and root biomass. Whilst Singh *et al.* (2010) stated that the tolerant groundnut cultivars to salinity stress had high field emergence, high plant population, low mortality and later produced high pod yield. K/Na ratio was also reported as an effective indicator for salinity tolerance (Mousa *et al.* 2014), because it positively correlated with yield and the tolerance level (Purwaningrahayu *et al.* 2016). The salinity stress symptoms might be different among genotypes because of the difference in salinity levels and growth phases (Putri 2016).

Peanut is sensitive to salinity stress, with the critical limit of 3.2 dS/m based on the yield (Yadav *et al.* 2011). Peanut germination delayed and even decreased at salinity of above 2 dS/m (Kristiono and Taufiq, 2015). Taufiq *et al.* (2015) reported yield decrease to more than 70% at EC above 4 dS/m. In fact, soil EC in the field varied from 8 to 12 dS/m (Purwaningrahayu and Taufiq 2018), and between 6 and 17 dS/m (Pratiwi and Nugrahaeni 2018). Therefore, the availability of peanut cultivar tolerant to salinity of above 4 dS/m is urgently needed. For this reason, peanut genetic resources that tolerant to salinity need to be identified.

The aim of this study was to evaluate 25 peanut germplasm accessions of Indonesian Legumes and Tuber Crops Research Institute collection for the tolerance to salinity stress. The accession which is identified tolerant to salinity >4 dS/m can be used as a gene resource for peanut breeding as well as a promising line that can be developed to a new cultivar.

MATERIALS AND METHODS

The experiment was conducted in a green house of Indonesian Legumes and Tuber Crops Research Institute (ILETRI) from March to July 2018, consisted of two factors that were arranged in a split plot design, three replications. The main plot was three salinity levels i.e. S0: non-saline as check, S1: moderate saline (5-6 dS/m), and S2: high saline (8-10 dS/m), while the subplot was 25 peanut accessions from germplasm collection unit of ILETRI (Table 1). The experiment used non saline soil from Muneng Experimental Station, Probolinggo with EC of 0.044 dS/m, pH 7.5 (slightly alkaline), and high exchangeable Ca and K. Soil salinity was adjusted to the values as in the treatments using natural sea water at certain concentrations. The seawater was taken from Balekambang Beach, South Malang (EC of 50.8 dS/m). Fertilizers at doses of 3 g of Phonska (15% N - 15% P_2O_5 - 15% K_2O), 1.2 g of SP36 (36% P_2O_5), 1.2 g of Urea (46% N), and 30 g of organic fertilizer per pot (7.5 kg air dried soil) were applied at sowing date.

Each pot was watered using 1500 mL tap water (EC of 0.66 dS/m) for S0, and with seawater at concentration of 5% for S1 and S2 at sowing date, and then maintained at field capacity by adding 265 mL/day (gravimetric base). Soil EC of S1 and S2 were adjusted to the values according to the treatment by addition of 265 mL/day of seawater at concentrations of 5% for S1 and 15% for S2 starting from 21 days after sowing (DAS) to 48 DAS. After 48 DAS, S1 and S2 were watered with 3-5% seawater to maintain soil EC at required ranges, and monitored every week using Hanna portable water conductivity and soil activity type HI 993310.

Salt toxicity scores were observed at 42 and 87 DAS using 1 to 9 scales based on the appearance of toxicity symptoms at the leaves as developed by Ledesma *et al.* (2016) (Tabel 2). K and Na contents in shoots and roots at 60 DAS were measured on selected accessions representing tolerant, moderate, and susceptible. Variables observed at harvest were the number of filled pods, pods and seeds weight. The collected data were analyzed using analysis of variance followed by Least Significant Difference at 5% probability using PKBT-STAT 1.0 software.

Table 1. Peanut accessions used in the research. ILETRI, 2018

Number	Accession codes	Name (status)	Number	Accession codes	Name (status)
1	MLGA 0108	NCAC 17133 (I)	14	MLGA 0523	JPO-10 (L)
2	MLGA 0211	Local Tegal (LV)	15	MLGA 0529	JPO-17 (L)
3	MLGA 0222	Mani Blanco (I)	16	MLGA 0536	ICGV 86371 (I)
4	MLGA 0294	ICGV 91099 (I)	17	MLGA 0541	Zebra (V)
5	MLGA 0304	Komodo (V)	18	MLGA 0546	ICGV 90220 (I)
6	MLGA 0336	ICGV 87160 (I)	19	MLGA 0551	Pelanduk (V)
7	MLGA 0361	ICGV 90046 (I)	20	MLGA 0570	Ristek-16 (L)
8	MLGA 0373	ICGV 90227 (I)	21	MLGA 0588	UNILA-6 (L)
9	MLGA 0473	Anoa (V)	22	MLGA 0605	Hypoma 1 (V)
10	MLGA 0479	PL-Biga (LV)	23	MLGA 0611	KT-M-15 (LV)
11	MLGA 0494	L. Tanjung NTB (LV)	24	MLGA 0616	Hypoma 2 (V)
12	MLGA 0513	UML 17-7 (L)	25	MLGA 0629	L. Sillo-NTT (LV)
13	MLGA 0519	JPO 6 (I)			

Note: I: introduced genotype, LV: local variety; V: improved variety, L: line

Table 2. Salt toxicity score

Score	Visual symptoms
1	Healthy dark green leaf with no chlorosis
2	Stunted dark green leaf, no chlorosis
3	Green yellowish leaf, smaller leaf size
4	Slight chlorosis leaf
5	Moderate chlorosis leaf
6	Severe chlorosis leaf, but no necrotic
7	Severe chlorosis leaf with some leaves edge partially necrotic
8	Necrotic leaf with small part show no necrotic
9	Severe necrotic leaf

Source: Ledesma et al. (2016). Score 1: normal, Score 2-3: low, 4-6: moderate, and 7-9: high

The salinity tolerance was assessed using Stress Tolerance Index (STI) value according to Fernandez (1992), i.e:

STI = (YP × YS) / vp2

YP: yield of certain genotype without salinity stress (g/plant)

YS: yield of certain genotype under salinity stress (g/plant)

vp: average yield of all tested genotype without salinity stress (g/plant)

The level of tolerant accession was determined based on the higher STI value and the ability to form pods and seeds.

RESULTS AND DISCUSSION

Soil EC

Salinity treatments applied at 21 DAS increased soil EC of S1 and S2 at the required ranges (Figure 1). Soil EC at S1 was 5-6 dS/m from sowing until physiological maturity, while at S2 was 5-6 dS/m from sowing until 20 DAS and 8-10 dS/m from 28 DAS until physiological maturity. The soil ECs at S1 and S2 were above the critical limit for peanut (3.2 dS/m). According to Kristiono and Taufiq (2015), the emergence and early growth phase of peanuts were very sensitive to salinity stress. The soil EC at S0 was 1.5-2 dS/m and it was categorized as slightly saline according to Yadav *et al.* (2011). This soil condition did not influence peanut growth. Figure 1 showed that the soil ECs fluctuated during the period of plant growth as also identified in the field (Pratiwi and Nugrahaeni, 2018).

Salt Toxicity Scores

Salt toxicity symptoms began with reduction of leaf size and plant height, leaf chlorosis, and then leaf edge necrosis. In advanced toxicity, the plants were withered, the leaf necrosis was spread and finally the entire plant leaves turn brown and died. Toxicity scores significantly increased as salinity increased, and no tolerance differences among the accessions (Table 3). At 42 DAS, there was no

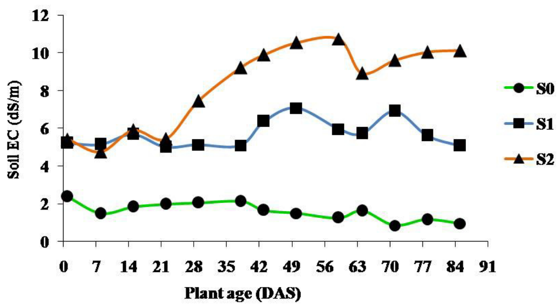

Figure 1. Soil ECs during peanut growth (S0: non-saline, S1: 5-6 dS/m, and S2: 8-10 dS/m).

Table 3. Salt toxicity scores on peanut accessions at 42 and 87 DAS at three salinity levels. ILETRI 2018

Number	Accessions	42 DAS			87 DAS		
		S0	S1	S2	S0	S1	S2
1	MLGA 0108	1.0	1.8	2.0	1.0	3.0	8.0
2	MLGA 0211	2.8	2.0	3.0	1.0	7.8	8.8
3	MLGA 0222	1.0	2.0	2.0	1.0	7.8	5.3
4	MLGA 0294	1.0	2.0	2.3	1.0	4.5	6.5
5	MLGA 0304	1.0	2.3	2.0	1.0	4.5	7.3
6	MLGA 0336	1.0	2.0	2.0	1.0	4.5	7.8
7	MLGA 0361	1.0	1.5	2.5	1.0	3.0	6.0
8	MLGA 0373	1.0	2.0	2.5	1.0	5.8	8.3
9	MLGA 0473	1.0	2.0	3.0	1.0	4.0	8.0
10	MLGA 0479	1.0	2.0	5.5	1.0	4.0	7.0
11	MLGA 0494	1.0	2.0	3.0	1.0	5.5	6.0
12	MLGA 0513	1.0	2.3	3.3	1.0	7.0	6.5
13	MLGA 0519	3.0	3.8	3.5	1.0	6.0	7.0
14	MLGA 0523	1.0	4.5	4.0	1.0	5.0	7.0
15	MLGA 0529	1.0	2.5	2.0	1.0	4.5	7.8
16	MLGA 0536	1.0	2.5	2.0	1.0	7.0	8.0
17	MLGA 0541	1.0	2.0	2.5	1.0	5.5	8.3
18	MLGA 0546	1.0	2.0	2.0	1.0	5.0	4.5
19	MLGA 0551	1.0	2.0	2.5	1.0	5.5	6.8
20	MLGA 0570	1.0	2.0	2.0	1.0	4.5	7.5
21	MLGA 0588	1.0	3.5	2.0	1.0	4.0	4.8
22	MLGA 0605	1.0	3.0	3.0	1.0	6.0	8.3
23	MLGA 0611	1.0	2.0	2.0	1.0	7.8	7.3
24	MLGA 0616	1.0	2.0	2.0	1.0	5.8	7.0
25	MLGA 0629	1.0	3.0	2.0	1.0	4.0	7.0
Average		1.2b	2.3a	2.6a	1.0c	5.3b	7.1a

Notes: DAS=Days After Sowing, S0: non-saline, S1: EC 5-6 dS/m, S2: EC 8-10 dS/m. Numbers in the same observation date followed by different letters indicate significantly different at LSD 5%. Score 1: normal, Score 2-3: low toxicity , 4-6: moderate toxicity, and 7-9: high toxicity symptoms.

toxicity symptoms presence in all accessions at S0, except MLGA 0211 and MLGA 0519 exhibited low toxicity that were probably susceptible to high soil pH (pH was 7.5 or slightly alkaline). All accessions showed low toxicity at salinity of S1 and S2, except one accession with moderate toxicity in S1 (MLGA 0523) and in S2 (MLGA 0479) (Table 3). The results indicated that all accessions up to 42 DAS were tolerant to salinity 8-10 dS/m, except MLGA 0523 and MLGA 0479 with moderately tolerant at salinity less than 5-6 dS/m and 5-6 dS/m, respectively.

At 87 DAS, all accessions showed moderate toxicity in S1, except two accessions with low toxicity (MLGA 0108 and MLGA 0361), and five accessions with high toxicity (MLGA 0211, MLGA 0222, MLGA 0513, MLGA 0536, and MLGA 0611). At salinity of S2, all accessions showed high toxicity, except five accessions (MLGA 0222, MLGA 0361, MLGA 0494, MLGA 0546, and MLGA 0588) with moderate toxicity (Table 3). Variability of toxicity scores among accessions indicates their different tolerances to salinity. The result indicates that their salinity tolerance not only depend on the level of salinity, but also on the length of exposure. According to Singh *et al.* (2008), peanut genotypes with high susceptibility to saline conditions show toxicity symptoms at the beginning of their growth and earlier mortality, while tolerant genotypes persisted. Juwarno *et al.* (2018) reported that tolerant cultivar had tendency of increasing chlorophyll content as salinity increase, therefore it could maintain the green leaves.

Peanut Yield

Number and weight of filled pods, as well as weight of seeds significantly decreased as salinity increased. Number of filled pods, weight of filled pods, and weight of seeds at salinity S1 reduced by 89%, 89%, and 91%, respectively compared to control treatment, and they reduced by 100% at salinity of S2 (Table 4 and Table 5). The crop yield decrease as the salinity increase was due to the decrease of water uptake and photosynthetic ability

a

b

Figure 2. Performance of tolerant accession (a) and sensitive accession (b) at salinity of 5-6 dS/m (S1) and 8-10 dS/m (S2)

Table 4. Number and weight of filled pods, and seed weight of peanut accessions under three salinity levels. ILETRI 2018

Number	Accessions	Number of filled pods per plant			Weight of filled pods (g/plant)			Weight of seeds (g/plant)		
		S0	S1	S2	S0	S1	S2	S0	S1	S2
1	MLGA 0108	22	1	0	45.90	4.10	0.00	34.70	1.31	0.00
2	MLGA 0211	25	5	0	48.63	12.91	0.00	36.60	8.24	0.00
3	MLGA 0222	17	6	0	44.22	20.56	0.00	32.23	14.05	0.00
4	MLGA 0294	21	1	0	64.38	3.73	0.00	45.03	1.89	0.00
5	MLGA 0304	18	1	0	40.42	2.91	0.00	29.01	1.46	0.00
6	MLGA 0336	20	1	0	45.40	1.48	0.00	33.29	0.84	0.00
7	MLGA 0361	16	4	0	43.80	12.58	0.00	30.21	7.08	0.00
8	MLGA 0373	18	1	0	45.77	1.11	0.00	31.57	0.51	0.00
9	MLGA 0473	18	0	0	58.37	0.00	0.00	41.54	0.00	0.00
10	MLGA 0479	18	1	0	40.79	2.45	0.00	28.79	1.15	0.00
11	MLGA 0494	18	1	0	41.72	1.11	0.00	28.74	0.48	0.00
12	MLGA 0513	22	2	0	36.41	2.34	0.00	26.08	1.44	0.00
13	MLGA 0519	19	3	0	76.98	8.10	0.00	56.34	3.73	0.00
14	MLGA 0523	22	6	0	41.60	12.38	0.00	30.10	6.85	0.00
15	MLGA 0529	19	1	0	41.12	3.24	0.00	29.15	1.74	0.00
16	MLGA 0536	23	2	0	53.06	3.95	0.00	40.61	2.64	0.00
17	MLGA 0541	13	2	0	44.50	5.30	0.00	31.68	2.74	0.00
18	MLGA 0546	24	2	1	105.83	6.29	0.34	75.58	3.31	0.15
19	MLGA 0551	21	1	0	40.71	2.40	0.00	31.77	1.39	0.00
20	MLGA 0570	29	4	0	105.81	7.18	0.00	79.10	3.86	0.00
21	MLGA 0588	14	3	0	41.30	10.58	0.00	31.36	5.05	0.00
22	MLGA 0605	18	0	0	39.84	0.00	0.00	27.26	0.00	0.00
23	MLGA 0611	18	5	0	40.26	3.25	0.00	29.96	1.89	0.00
24	MLGA 0616	16	2	0	43.08	6.50	0.00	31.23	3.13	0.00
25	MLGA 0629	16	3	0	40.24	9.28	0.00	28.06	5.13	0.00
Average		19a	2b	0c	50.80a	5.75b	0.01 c	36.80a	3.20b	0.01c

Notes: S0: non-saline, S1: salinity of 5-6 dS/m, S2: salinity of 8-10 dS/m. Numbers in the same variable followed by different letters indicate significantly different at LSD 5%.

(Acosta-Motos *et al.* 2017). High salt concentrations decrease the osmotic potential of soil, which reduce the water uptake and disrupts the transport of water and nutrients, furthermore, water deficit causes a leaf turgor decrease at causes stomata closure and reduces stomatal conductance. This is the reason that high salt concentration is one of the factors limiting photosynthesis rates (Hnilièková *et al.* 2017.

At salinity of S1, all accessions were able to form pods except MLGA 0473 and MLGA 0605. At salinity of S2, however all accessions were unable to form pods except MLGA 0546 with less pods and seeds (Table 4). This result showed that almost all of tested accessions survived and produced pods at soil EC of 5-6 dS/m, but failed to produce pods at EC of 8-10 dS/m since the plants exihibited severe saline toxicity (Figure 2).

Salinity Tolerance

Yield and yield component losses of all accessions were more than 80% as the salinity increased from normal to 5-6 dS/m, except MLGA 0222 with 55% of yield and yield component losses (Table 5). In other words, all accessions were experiencing severe salt stress at salinity of 5-6 dS/m. However, four accessions (MLGA 0211, MLGA 0222, MLGA 0546, and MLGA 0570) were identified as tolerant under moderate salinity (EC 5-6 dS/m) based on its Stress Tolerance Index (STI) (Table 5). The high STI values in MLGA 0211 and MLGA 0222 related to less yield loss, while the other two accessions (MLGA 0546 & MLGA 0570) were related to their high yields under normal condition. MLGA 0211 was a local cultivar that was collected from Tegal, a district in Central Java which is located in the north coast area. The tolerant characterization of MLGA 0211 could be triggered from the origin location. MLGA 0222 was introduced from overseas with the name of Mani Blanco, while MLGA 0546 was introduced from ICRISAT India. MLGA 0570 was a line from colaborative research project with Ministry of Research and Technology. Two accessions (MLGA 0473 and MLGA 0605) were sensitive to salinity of

Table 5. The percentage of yield reduction and stress tolerance index (STI) of 25 peanut accessions at EC of 5-6 dS/m (ILETRI 2018)

Number	Accessions	Yield and yield component reduction compared to check (%)			STI of filled pods weight	STI of seeds weight	Classification
		Number of filled pods	Filled pods weight	Seeds weight			
1	MLGA 0108	97	91	96	0.07	0.03	M
2	MLGA 0211	81	73	77	0.24	0.22	T
3	MLGA 0222	67	54	56	0.35	0.33	T
4	MLGA 0294	94	94	96	0.09	0.06	M
5	MLGA 0304	93	93	95	0.05	0.03	M
6	MLGA 0336	95	97	97	0.03	0.02	M
7	MLGA 0361	73	71	77	0.21	0.16	M
8	MLGA 0373	97	98	98	0.02	0.01	M
9	MLGA 0473	100	100	100	0.00	0.00	S
10	MLGA 0479	96	94	96	0.04	0.02	M
11	MLGA 0494	97	97	98	0.02	0.01	M
12	MLGA 0513	93	94	94	0.03	0.03	M
13	MLGA 0519	84	89	93	0.24	0.15	M
14	MLGA 0523	75	70	77	0.20	0.15	M
15	MLGA 0529	93	92	94	0.05	0.04	M
16	MLGA 0536	91	93	93	0.08	0.08	M
17	MLGA 0541	88	88	91	0.09	0.06	M
18	MLGA 0546	93	94	96	0.26	0.18	T
19	MLGA 0551	95	94	96	0.04	0.03	M
20	MLGA 0570	88	93	95	0.29	0.23	T
21	MLGA 0588	78	74	84	0.17	0.12	M
22	MLGA 0605	100	100	100	0.00	0.00	S
23	MLGA 0611	72	92	94	0.05	0.04	M
24	MLGA 0616	91	85	90	0.11	0.07	M
25	MLGA 0629	83	77	82	0.14	0.11	M

Notes: S=sensitive; M=moderate, T=tolerant.

5-6 dS/m which were indicated by its inability to produce pods (Figure 3). The ability to produce seeds in saline environment is an important indicator of salinity tolerance of peanut plant (Singh et al. 2008; Singh et al. 2010; Azad et al. 2014).

MLGA 0473 did not produce any pod at salinity level of 5-6 dS/m, but this accession had good vegetative growth, where leaves remained green with moderate toxicity score at 87 DAS. In contrast, MLGA 0211 and MLGA 0222 produced many pods, even though they showed high toxicity score at 87 DAS. This indicated two different mechanisms for dealing with salinity stress. The first mechanism was stress avoidance as shown MLGA 0473. The accession allocated more energy from photosynthesis to cope with stress and still growing. The second mechanism was stress escape as shown by MLGA 0211 and MLGA 0222 where these accesions accelerated their life cycle and used energy efficiently and resulted in higher pod yield. Therefore, MLGA 0473 is prospective to be used as a source of salinity tolerant gene based on its survival in saline conditions, while MLGA 0211 and MLGA 0222 as sources of genes for the ability to produce pods. MLGA 0108 and MLGA 0361 were classified as moderate because of its low toxicity scores. Crossing with these accessions may improve the tolerance characters to saline soil.

Ratio of K and Na in Root and Shoot

Increasing salinity levels increase Na and reduce K concentration in peanut root and shoot (Aydin akir et al. 2015; Meena et al. 2018). Decreasing K content causes chlorosis or necrosis and inhibits the formation of peanut pods and seeds (Gopal 2012). The K/Na ratio represents dynamic relationship between K and Na uptake. The K/Na ratio in root and shoot in non saline soil was consequtively 3-6 and 5-7 folds higher than that at salinity of 5-6 dS/m (Table 6). This indicates that increasing salinity increases Na and reduces K uptake.

Figure 3. Pods and seeds performance of tolerant accession (left) and sensitive accession (right) at S0 (check) and S1 (salinity 5-6 dS/m). ILETRI 2018

Ratio of K/Na in shoot of tolerant accessions was higher than that in moderate and sensitive accessions, and in contrast for K/Na ratio in root. The ratio of K/Na in roots under saline condition was less than 1, which indicated that Na concentration was higher than K concentration. The K/Na ratio in root was lower than that in shoot which indicated there was an inhibition mechanism of Na distribution from root to shoot. The K/Na ratio in shoot of tolerant accessions was higher compared to that in moderate and sensitive accessions (Table 6). It seems that K/Na ratio in shoot is more appropriate as an indicator for salinity tolerance than that of K/Na in root. These results were in line with Singh *et al.* (2010; 2016). High selectivity for K^+ ions and restriction for Na^+ uptake are the parts of salinity tolerance mechanism (Chakraborty *et al*. 2013). Tolerant cultivar showed greater resistance in Na uptake and its further accumulation in different plant parts (Chakraborty *et al.* 2016).

Ratio of Na-root/Na-shoot in tolerant accessions was higher than that in moderate and sensitive accessions (Table 6). This indicated that there was inhibition mechanism of Na uptake as well as limitation of Na translocation from root to shoot, so that K/Na ratio in shoot remained high. Potassium in plant acts as a regulator and is a constituent of more than 65 different enzyme systems of drought tolerance and water use efficiency. Although potassium is not an essential component of cell structure, it regulates many biochemical processes which is essential for growth, development and seed production (Jha and Subranian 2016). The results also implied that Na-root/Na-shoot ratio as an effective indicator for salinity tolerance beside K/Na ratio in shoot.

Beside the ability to grow with low mortality can be categorized as tolerant, the most important indicator of tolerance in peanut plants is their ability

Table 6. Ratio of K/Na in root and shoot and ratio of Na-root/Na-shoot of peanut accessions with different salinity tolerance at 60 DAS, ILETRI 2018

Accessions	Toxicity score in S1 at 87 DAS	Category of tolerance based on STI	K/Na ratio in root		K/Na ratio in shoot		Na-root/Na-shoot ratio	
			S0	S1	S0	S1	S0	S1
MLGA 0211	7.8	Tolerant	2.70	0.74	44.67	5.34	8.30	3.70
MLGA 0222	7.8	Tolerant	2.47	0.89	35.17	5.84	12.20	5.40
MLGA 0546	5.0	Tolerant	2.61	0.79	18.00	7.46	3.80	3.20
Averages			2.59	0.81	32.61	6.21	8.10	4.10
MLGA 0361	3.0	Moderate	3.33	0.44	33.88	4.36	3.00	2.90
MLGA 0108	3.0	Moderate	2.49	0.74	33.17	3.79	9.80	1.20
MLGA 0611	7.8	Moderate	2.54	0.37	16.40	4.37	2.30	3.20
MLGA 0629	4.0	Moderate	3.62	0.37	25.60	2.50	2.90	3.30
Averages			3.00	0.48	27.26	3.76	4.50	2.65
MLGA 0605	6.0	Sensitive	4.79	0.90	29.89	4.31	3.20	1.70

Notes: S0: non saline; S1: salinity 5-6 dS/m; DAS: days after sowing.

to form pods and seeds (Singh *et al.* 2010; Azad *et al.* 2014). The accessions that were identified as tolerant based on their ability to form pods and seeds and withstand on the effects of salinity can be employed and integrated in peanut breeding for salinity tolerance. Moreover, genotypes with potential yield under normal condition also have potential tolerance in stress condition because it has a positive correlation with the yield under stress (Paula *et al.* 2019). On other hand, the ratio of Na-root/Na-shoot will be the new selection indicator of peanut tolerance to salinity stress. The identification of salt tolerant accessions in this study provides information that peanut is able to be cultivated in saline soil and potentially provide additional income for farmers.

CONCLUSION

Soil salinity of 5-6 dS/m was the highest salinity level where 23 accessions were able to grow and produce pods. At higher salinity (EC 8-10 dS/m), the accessions showed severe toxicity and were unable to produce pods and seeds. At EC of 5-6 dS/m, four accessions were identified tolerant (MLGA 0211, MLGA 0222, MLGA 0546, and MLGA 0570), two accessions were sensitive (MLGA 0473 and MLGA 0605), and 19 accessions were moderate. The tolerance mechanism of tolerant accessions was through inhibiting Na uptake and limiting translocation of Na to the shoots. The Na-root/Na-shoot ratio was the effective indicator of salinity tolerance beside K/Na ratio in shoot.

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