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Research Article

Effect of amelioration on growth and yield of two groundnut varieties on saline soil

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Abstract: Productivity of agricultural land in coastal area is limited by salinity. Planting tolerant variety combined with amelioration is an effective management to increase productivity of salt affected land. The objective of this study was to identify effective ameliorant for improving growth and yield of groundnut on saline soil. The trial was conducted on saline soil in Tuban from May to September 2015. The trial consisted of two factors that were arranged in a completely randomized block design, three replications. The first factor was two groundnut varieties (Domba and Hypoma 1). The second factor was six soil ameliorations (control, 120 kg/ha K2O, 2.5 t/ha dolomite, 2,5 t/ha of gypsum, 2.5 t/ha of manure, and 1.5 t/ha of gypsum + 2.5 t/ha of manure). Results showed that Domba and Hypoma 1 varieties could tolerate and completed their life cycle at *insitu* saline condition. Hypoma 1 was more prospective to be developed in saline condition associated with higher survival as well as better pod setting and seed development than Domba. Combination of gypsum and manure provided better effect than other treatments in improving saline soil, since it reduced exchangeable Na, Na saturation, and EC of soil, and also improved groundnut yield.

***Keywords**: amelioration, groundnut, saline soil*

Introduction

Agriculture land degradation due to salinity is one of the national issues (Las *et al*. 2006). Increasing salinity of agriculture land may be due to intensive use of water irrigation (Pessarakli and Tucker, 1988), water pollution (Dajic, 2006; Suganda et al., 2009), see water flooding such as in Aceh (Rachman et al., 2008), and see water intrution such as in Indramayu (Marwanto et al., 2009; Erfandi and Rachman, 2011). In 2015, we ramdomly measured electrical conductivity (EC) of paddy field in coastal area at Palang Subdistrict (Tuban District) and Brondong Subdistrict (Lamongan District) at tillering phase of rice, and we found the EC of 4.4 to 8.0 dS/m (using Hanna portable EC meter type HI993310). There are 500 ha of salt affected paddy field (estimates based on google map) in these sites, and farmer only planting rice once a year during rainy season.

On saline condition, concentration of Na and Cl in leaf is very high and toxic (Dogar et al., 2012), and these ions reduce absorbtion of K^+, NO_3^-, and $H_2PO_4^-$ (White and Broadley, 2001; Tester and Davenport, 2003). Salinity induce imbalance nutrient (Rogers et al., 2003; Hu and Schmidhalter 2005), and retard activity of Ca and K cations due to high ratio of Na^+/Ca^{2+} or Na^+/K^+ (Grattan and Grieve, 1999). High Na concentration in plant reduce absorption of Mg^{2+} (Hu and Schmidhalter, 1997), K^+ and Ca^{2+} (Asch et al., 2000; Hu and Schmidhalter, 2005), N and P, and also K translocation (Hirpara et al., 2005). Reduction of K absorbtion reduce activity of enzime nitrate reductase in change reaction of NO_3 to NH_3 (Hu and Schmidhalter, 2005).

Salinity retards crop growth and induces change of morphological as well as anatomy of plant (Cakmak, 2005), and affects on almost all crop growth stage (Nawaz et al., 2010). Germination of groundnut seed reduces 10% on media containing 2.5% NaCl (Mungala et al., 2008). Total chlorophyl content reduces due to increasing salinity from 7.5 dS/m to 9.2 (Hammad et al,. 2010). The most critical stage to salinity is seedling and seed development stages (Kitajima and Fenner, 2000; Mudgal, 2004; Cuartero et al., 2006), and flowering stage (Amin, 2011). Groundnut yield reduction of 25%, 50%, and 100% consecutively were observed on salinity level of 4.1, 4.9, and 6.5 mmhos/cm (Mungala et al., 2008). Yadav et al. (2011) found that EC 3.2 dS/m is critical value for groundnut based on yield reduction. From greenhouse trial showed that ten Indonesian groundnut varieties tested failed to produce pod on soil with EC about 2.0 dS/m (Taufiq et al., 2015).

The use of tolerant cultivars is an economical way to solve the salinity problem. Nevertheless, amelioration is needed when salinity above the level that can be tolerated by crops. Amelioration using P and K fertilizers, manure, ash, and dolomite were effective in increasing yield of rice and palawija crops (Sembiring et al., 2008; Iskandar and Chairunas, 2008). Th objective of this study was to identify effective ameliorant for improving growth and yield of groundnut on saline soil.

Materials and Methods

On farm trial was conducted at Gesikharjo village, Palang Sub District, Tuban District (6^{o}54'20.396" S, 112^{o}8'18.118" E; 30 m abs). Sowing was conducted on 4 June and was harvested on 1 October 2015. Soil charracteristics at the site are presented in Table 1.

The trial that consisted of two factors was laid out in a completely randomized block design with three replicates. The first factor was two groundnut varieties (Domba and Hypoma 1), where Domba belong to spanish type and Hypoma 1 belongs to valencia type. The second factor was six kind of amelioration consisting of control, 120 kg/ha K_2O, 2.5 t/ha dolomite, 2.5 t/ha gypsum, 2.5 t/ha organic manure (OM), and combination of 1.5 t/ha gypsum + 2.5 t/ha OM. Agricultural dolomite (80 mesh) bought from retailer in Lamongan containing 26.2% CaO and 15.2% MgO (extraction 25% HCl). Gypsum used for this study contained 20.7% CaO and 0.6% MgO that was produced by PT. Petrokimia Gresik. Organic manure used for this study was produced by CV. Sumberagung Malang containing 5.6% C-organic, 0.34% N, 0.99% K, 0.89% Ca, and 0.68% Mg. Analysis of dolomite and organic manure was conducted at Iletri's Laboratory.

Land preparation was done by clearing the previous crop residue (rice), and no soil tillage. Contact herbicide was applied before planting to control weeds. Plot size was 4 m x 3 m, and inter plot separated by drainage canal. Brodcast application of ameliorant was in accordance with the treatment applied just before sowing. Groundnut seeds (1-2 seeds/hole) were planted at spacing of 40 cm x 15 cm, then covered with soil. Basal fertilization that consisted of 33.7 kg N/ha, 36 kg P_2O_5/ha and 30 kg K_2O/ha was broadcasted just after planting. Tilling and hilling up soil were made at 25 days after planting (DAP). Another 22.5 kg N/ha was applied at 50 DAP. Irrigation was applied seven times from 15 up to 65 DAP with 7 days interval, and at 80 DAP. Irrigation came from well at trial site with EC of water 2.65 dS/m (first up to third irrigation) and EC 4.08 dS/m (fourth up to seventh irrigation). Manual weeding was conducted three times at 20, 45, and 75 DAP. There were no pest and disease during crop growth and therefore no pesticide was applied.

Soil analysis that was conducted before planting and at harvest consisted of EC, pH, C-Organic, exchangeable Na, Ca, Mg, and K. Before planting, soil sample collected from all plots at soil depth of 0-20 cm and 20-40 cm, and then composite according to soil depth. At harvest, soil sample was collected from each plot at soil depth of 0-20 cm and then composited according to the treatment.

Tissue analysis of above ground plant part at maximum vegetative growth consisted of Na, Ca, Mg, and K. Five samples were collected from each plot (out side of harvesting plot), oven dried at 75 ^{o}C up to constant weight, then ground and composite during grinding according to the treatment. Soil and plant analyses were conducted at Iletri's Laboratory according to Eviati and Sulaeman (2009).

Plant height was recorded at 15, 30, 45, 60 and 75 DAP, by measuring lenght of main stem of five plants each plot. Chlorophyl content index at was recorded at 15, 30, 45, 60 and 75 DAP, by measuring leave of five plants each plot using Chlorophyl meter SPAD-500.

Dry weight of shoot at maximum vegetative growth 10 plant samples each plot , oven dried at 105 ^{o}C up to constant weight. Data collection at harvest consisted of number of harvested plant, number of filled and immature pods, fresh and sun dry weight of pods, and weight of dry seeds.

Results and Discussion

Soil chemical properties

Electrical condutivity (EC), pH, exchangeable (exch)-K, Ca, Mg, and Na of soil at trial site were high, but Na saturation was low (Table 1). The soil is clasified as saline soil according to Gorham (2007) and Sposito (2008). The site that is located 500 m from the coast, is situated in a valley surrounded by limestone hills. Sea water flow into the canal up to 1.5 km from the coast during dry season. During the trial, EC of ground water varied from 2.65 dS/m to 4.08 dS/m.

Table 1. Soil chemical properties at trial site.

Soil parameters	**Method**	**Soil depth (cm)**	
		0-20	**20-40**
pH-H_2O	5:1	7.7	8.3
C-organic (%)	Kurmis	2.27	1.26
Exch-K ($cmol^+$/kg)	1 N NH_4OAc pH 7	1.80	1.80
Exch-Na ($cmol^+$/kg)	1 N NH_4OAc pH 7	2.33	1.58
Exch-Ca ($cmol^+$/kg)	1 N NH_4OAc pH 7	43.70	39.10
Exch-Mg ($cmol^+$/kg)	1 N NH_4OAc pH 7	15.50	15.60
CEC ($cmol^+$/kg)	1 N NH_4OAc pH 7	48.20	71.40
EC (dS/m)	Soil:water 1:1	15.33	7.05
EC (dS/m)	Soil:water 1:2	7.66	3.53
Na saturation (ESP, %)	(Na/CEC)*100	4.83	2.21
SAR (sodium adsorption ratio)	$Na/\sqrt{[(Ca+Mg)/2]}$	0.43	0.30

Soil EC with dilution ratio of 1:2 (soil:water) was classified as very saline according to classification adopted by Georgia University (Sonon *et al*. 2015). Soil fertility was high based on exch-K, Ca, and Mg content. Soil EC level was above the critical level of 3.2 dS/m for groundnut according to Yadav *et al*. (2011), and so that limited groundnut growth. Green house trial showed that groundnut failed to perform pods at EC level of about 2.0 dS/m (Taufiq *et al*. 2015). Eventhought the EC level of soil above the critical level, but groundnut in this trial performed pods, and it might be due to soil contained high K, Ca, and Mg. Soil data after harvest showed that C-organic in all treatment was lower than control, except in organic manure (OM) treatment that increased by 1.4%, and exch-K also increased by 13 up to 19%. Comparing with soil analysis data before planting (Table 1), exch-Na reduced by 59%, Na saturation by 65%, and EC by 16%. The reduction might be due to leaching as irrigation applied seven times during crop growth. Among the amelioration treatments, only application of gypsum+OM reduced exch-Na, EC, and Na saturation by 10% compared with check (Table 2). It means that application of gypsum+OM is more effective in reducing exch-Na, EC, and Na saturation than the other treatments.

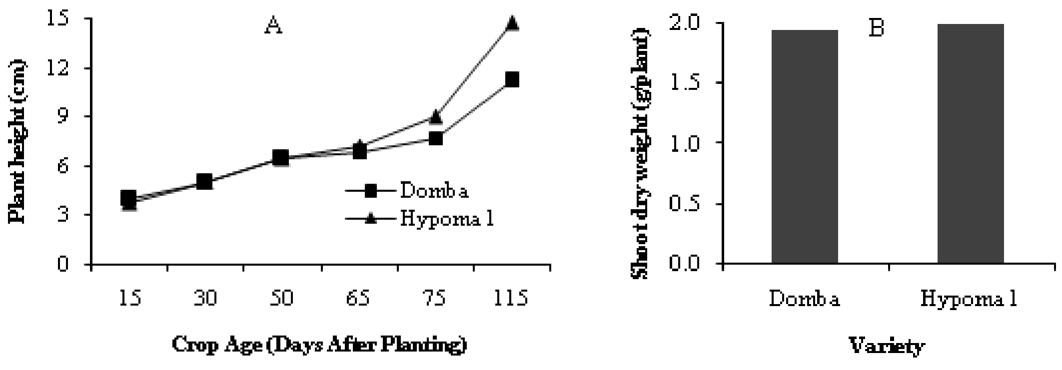
Table 2. Soil properties at 0-20 cm soil depth at harvest.

Amelioration treatments	**Soil Parameters**							
	pH-H_2O 1:2.5)	**C-org (%)**	**Exchangeable Cations ($cmol^+$/kg)**				**EC (1:2, dS/m)**	**Na sat. (%)**
			K	**Na**	**Ca**	**Mg**		
Control	8.6	2.84	1.67	0.95	38.45	14.90	6.14	1.69
K_2O	8.7	2.62	1.91	0.98	36.88	15.10	6.05	1.79
Dolomite	8.7	2.75	1.88	1.00	37.55	14.93	7.45	1.80
Gypsum (Gyp)	8.8	2.60	1.91	0.94	38.18	14.95	6.44	1.68
Organic manure (OM)	8.7	2.88	1.99	0.95	37.90	15.08	6.95	1.69
Gyp+OM	8.7	2.56	1.90	0.85	37.90	15.08	5.53	1.53

Crop growth

Growth of Domba and Hypoma 1 varieties was retarded, and no signficant different in plant height among the two varieties from 15 DAP up to 50 DAP ($p \geq 0.113$). Hypoma 1 grew higher than Domba ($p \leq 0.02$) starting from 65 DAP (Figure 1a), and it is because of Hypoma 1 is Spanish type while Domba is Valencia type. There was no signficant different of shoot dry weights of both varieties at 50 DAP, and it was about 2 g/plant (Figure 1b).

Soil amalioration using K fertilizer, organic manure (OM), gypsum, dolomite, and gypsum+OM did not improve plant height (p≥0.227), as well as shoot dry weight (p=0.38) (Figure 2). It indicates that ameliorant applied did not effectively improve groundnut growth. Soil analysis at harvest showed that EC level was still above the critical level of 3.2 dS/m according to Yadav et al. (2011). Stunted plant growth and low biomass accumulation indicate that salinity stress inhibited the growth of peanuts, and this was in accordance with Cakmak (2005).



A B

Figure 1. Plant height (A), and shoot dry weight (B) of Domba and Hypoma 1 varieties grown on saline soil in Tuban (LSD 5% for plant height at 65, 75, and 115 DAP consecutively 0.6, 0.5, and 2.0 cm).

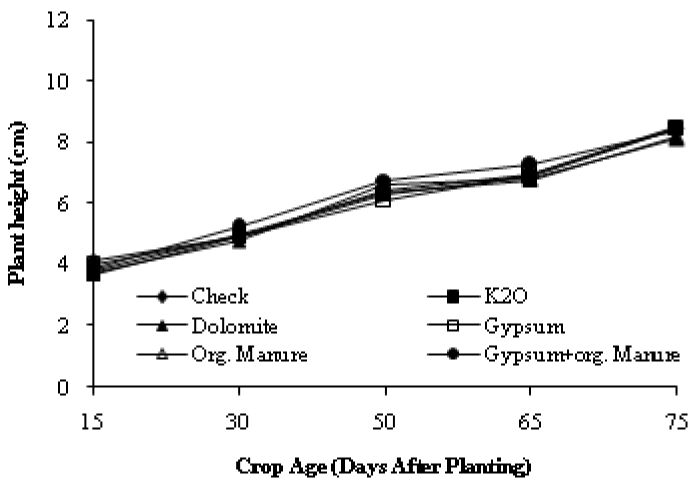


Figure 2. Effect of soil amelioration on plant height and shoot dry weight of groundnut on saline soil in Tuban.

Chlorophyl content index

In the trial, the seeds began to germinate and visible at above ground at about 10 DAP and looked normal. Chlorophyl Content Index (CCI) at 15 DAP is 42 indicating high chlorophyl content, and CCI was reduced to 30 at 30 DAP indicating low chlorophyl content (Figure 3). The CCI at level of 30, leaves colour showing yellowish like nitrogen (N) deficiency symptom. Leaves became normal green after 30 DAP as indicated by increasing the CCI to level of ≥35, means that both variety recovered. Mechanism of recovering migh be related to root development and root penetration into deeper soil layer with lower EC, exch-Na, and Na saturation (Table 1). The CCI of Hypoma 1 after 50 DAP was significantly higher than Domba (Figure 3), indicating that Hypoma 1 might be more tolerant to salinity than Domba. Salinity reduced N absorbtion (Hirpara *et al.* 2005), and total chlorophyl content (Hammad *et al.* 2010; Taffouo *et al.* 2010). Soil amelioration using K fertilizer, organic manure (OM), gypsum, dolomite, and gypsum+OM could not retard chlorophyl demage as indicated by decreasing the CCI at 30 DAP (Figure 4).

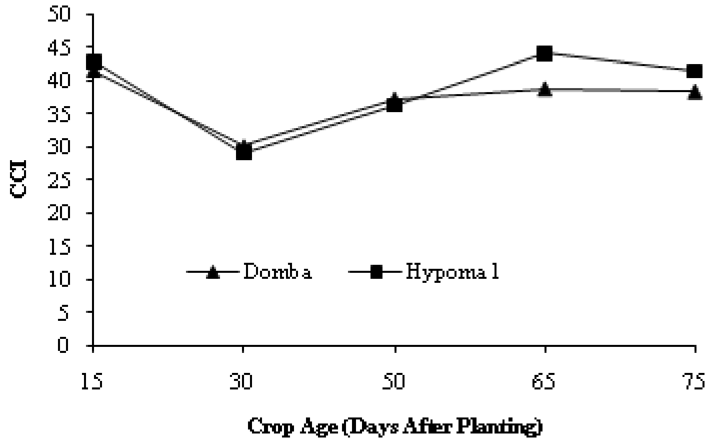


Figure 3. Chlorophyl Content Index (CCI) of groundnut of Hypoma 1 and Domba varieties on saline soil in Tuban (LSD 5% at 65 DAP=2.0 and 75 DAP=1.5).

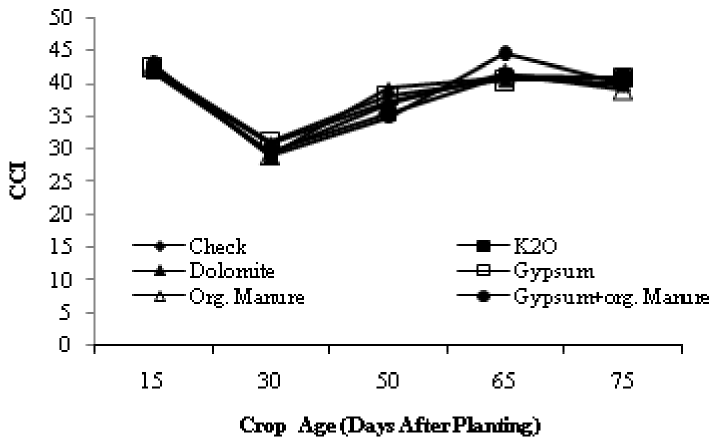


Figure 4. Effect of amelioration on Chlorophyl Content Index (CCI) of groundnut on saline soil in Tuban.

Yield and yield components

Number of branches of both variety tested was normal, but the number of filled pods was very low. Number of branches and filled pods of Hypoma 1 were higher than Domba. Therefore, Hypoma 1 had higher yield and harvest index (HI) than Domba. Weights of fresh and dry pods of Hypoma 1 consecutively 58% and 71% were higher than Domba. Productivity of Hypoma 1 was 1.8 t/ha fresh pods or 0.7 t/ha dry pods (Table 3). Low number of pod per plant and pod yield due to salinity effect was also reported by Taffouo *et al.* (2010). Weight of a 100 seeds of Domba variety was 31.1 g and Hypoma 1 was 41.5 g (Table 3). According to their discription, weight of a 100 seeds of Domba is 46.5-50.5 g and Hypoma 1 is 31.2 g. It means that on saline condition, seed size of Hypoma 1 was bigger, but Domba was smaller than in normal condition. Visual observations showed pod size was relatively normal, but pod shell especially on Domba variety was thicker than Hypoma 1. HI of groundnut in normal condition is about 0.47. The low HI indicates low photosyntate partition to the reproductive organs, and it might be related to reduction of K absorbtion and K translocation as reported by Asch *et al*. (2000), Hirpara *et al*. (2005), Hu and Schmidhalter (2005). Amelioration using K fertilizer, dolomite, gypsum, organic manure (OM), and gypsum+OM did not significantly affect fresh and dry pod yield, and it might be due to high coficient of variation. However, application of gypsum increased fresh pod yield by 12.6% and dry pod yield by 13.1%, and increased consecutively by 19.9% and 26.1% with application of gypsum+ OM (Table 3). The result showed that application of gypsum and gypsum+OM had better effect than other treatments on yield improvement, and it could be related to it's ability to reduce exch-Na, Na saturation, and soil EC.

Table 3. Effect of variety and amelioration on yield and yield components of groundnut on saline soil in Tuban.

Factors	Number/plant				Weight of pods (kg/ha)		Harvest index
	Branches	Filled pods	Empty pods	Immature pods	Fresh	Dry	
Variety							
Domba	5 b	4 b	3	6	1.127 b	436.0 b	0.18 b
Hypoma 1	6 a	8 a	4	5	1.782 a (58)[1)]	745.2 a (71)	0.27 a
Amelioration							
Check	5	6	3	6	1.435	564.9	0.24
K_2O	6	7	4	5	1.470 (2,4)[2)]	604.6 (7.0)	0.21
Dolomite	5	6	3	4	1.141 (-20,5)	469.9 (-16.8)	0.23
Gypsum (gyp)	6	5	3	4	1.616 (12,6)	638.9 (13.1)	0.21
Org. manure (OM)	6	8	4	5	1.344 (-6,3)	552.6 (-2.2)	0.27
Gyp+OM	6	7	4	6	1.721 (19,9)	712.5 (26.1)	0.23
Variety (V)	**	**	ns	ns	**	**	**
Amelioration (A)	ns	ns	ns	ns	ns	ns	ns
V*A	ns	ns	ns	ns	ns	ns	ns
CV (%)	7.9	41.1	44.9	40.7	43.1	46.9	35.4

Notes: numbers in one coloum in each parameter and factor with the same letter or no letter means not significantly different at LSD 5%;* and **= signficant at level of 5% and 1%;ns=not significant; [1)]increament percentage to Domba; [2)]increament percentage to check.

The weight of dry pods positively correlated with plant population at harvesting time (r=0.73, n=36) (Figure 5). Plant population of Hypoma 1 at harvesting time is 70%, while Domba is 60% of initial population (200 plants/plot). It means that mortality of Hypoma 1 is 30% and Domba is 40%. Singh *et al*. (2008) showed that mortality of non sensitive groundnut variety on salinity of >4 dS/m reached 50%, and 100% for sensitive variety. This indicates that Hypoma 1 and Domba variety are tolerant to salinity, but among the two, Hypoma 1 is more tolerant to salinity than Domba.

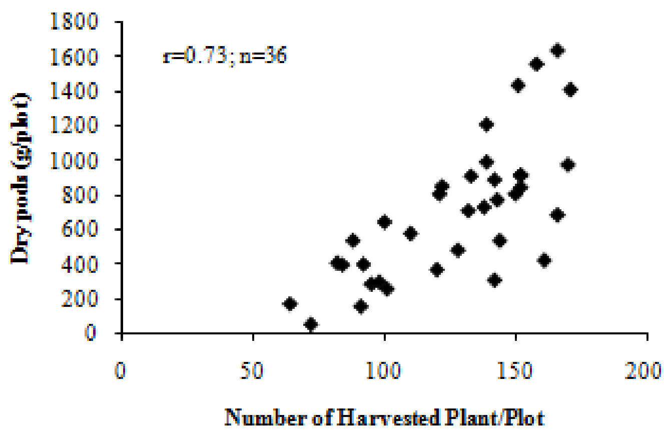


Figure 5. Correlation between number of harvested plant and weight of dry pods of groundnut of saline soil in Tuban (plot size=12 m^2).

Plant population at harvesting time on dolomite and OM treatment consecutively was 50% and 60% from the initial population (Figure 6), and these population was lower compared with the other treatments. This indicates that productivity of groundnut on saline condition determined by the mortality percentage that is related to degree of tolerancy of variety.

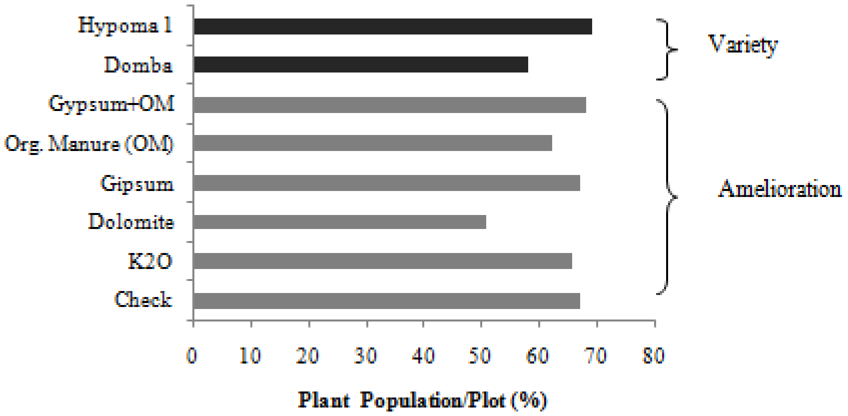


Figure 6. Percentage of plant population of two groundnut varieties (Domba and Hypoma 1) and amelioration treatment at harvesting time on saline soil in Tuban (plot size=12 m^2, initial plant population 200 plants/plot).

K, Na, Ca, and Mg Absorbtion

K content of shoot at 50 DAP (paging stage) was fair, but Ca and Mg contents were high. According to Fegeria (2009), sufficiency levels of K, Ca, and Mg content on groundnut shoot at paging stage is 1.7-3.0% K, 1.25-1.75% Ca, and 0.3-0.8% Mg, respectively. Domba variety absorbed more K than Hypoma 1 variety, but Hypoma 1 absorbed more Ca than Domba. Both varieties absorbed relatively similar amounts of Na and Mg (Table 4). Absorbtion of Ca reduce adverse effect of salinity (Nooghi and Mozafari, 2012; Shukla et al., 2010). Tolerancy of Domba variety might be related to higher K absorbtion, while Hypoma 1 variety was related to higher Ca absorbtion.

Comparing with check treatment, amelioration using K fertilizer, dolomite, gypsum, organic manure (OM), and gypsum+OM did not reduce Na absorbtion, increased K absorbtion except on gypsum+OM treatment, and increased Ca absortion (Table 4). The high Ca absortion reduced adverse effect of salinity as found by Nooghi and Mozafari (2012) and Shukla et al. (2010). However, Ca absortion on dolomite and OM treament might be too high that also had adverse effect on mobility of K in plant tissue.

Table 4. Effect of variety and amelioration on K, Na, Ca, and Mg content in shoot of groundnut at 50 days after planting (paging stage) grown on salin soil in Tuban.

Treatment	**Nutrient Content (%)**				**Nutrient Absorb tion (mg/plant)**			
	K	**Na**	**Ca**	**Mg**	**K**	**Na**	**Ca**	**Mg**
Variety								
Domba	1.89	0.30	2.28	1.22	36.8	5.8	44.3	23.7
Hypoma 1	1.71	0.27	2.34	1.20	33.3	5.3	45.5	23.3
Amelioration								
Check	1.79	0.28	1.94	1.20	34.8	5.4	37.7	23.3
K_2O	1.87	0.29	2.19	1.23	36.4	5.6	42.6	23.9
Dolomite	1.85	0.28	2.53	1.25	36.0	5.4	49.2	24.3
Gypsum (gyp)	1.86	0.29	2.24	1.15	36.2	5.6	43.6	22.4
Org. manure (OM)	1.77	0.28	2.52	1.18	34.4	5.4	49.0	23.0
Gyp+OM	1.69	0.28	2.42	1.24	32.9	5.4	47.1	24.1

The research results showed that Domba and Hypoma 1 varieties could grow and complete their life cycle in saline condition. Domba variety tolerant to salinity might be due to high K absorbtion, while Hypoma 1 might be due to high Ca absorbtion. Hypoma 1 yielded higher pods than Domba because of lower mortality in saline environments, and has better in seed development and seed filling. It seems that Hypoma 1 is more tolerant to salinity than Domba.

Salinity amelioration using combination of gypsum and organic manure has better effect in improving saline soil compared with amelioration using K fertilizer, dolomite, gypsum, and organic manure (OM) because it relatively consistent in reducing exchangeable Na, Na saturation, and soil EC, and also increase groundnut yield higher than the other treatment.

Conclusion

The use of saline-tolerant variety is the key to successful management of saline soils. Domba and Hypoma 1 varieties tolerant to saline because they can grow and completing their life cycle in saline condition. Hypoma 1 more prospective developed in saline condition because of higher productivity associated with higher survival as well as better pod setting and seed development. Combination of gypsum with manure provide better effect in improving saline soil due to the relatively consistent in reducing exchangeable Na, Na saturation, and soil EC, as well as the opportunity to improve the productivity of groundnut.

References

Amin, M. 2011. Adaptation of Suitable Crops in Saline Soils of Noakhali District. Technical Bull. No. 02. Krishi Gobeshona Foundation. Bangladesh. 5 pp

Asch, F., Dingkuhn, M., Dorffling, K. and Miezan, K. 2000. Leaf K/Na ratio predicts salinity induced yield loss in irrigated rice. *Euphytica* 113:109-118.

Cakmak, I. 2005. The role of potassium in alleviating detrimental effects of abiotic stresses in plants. *Journal of Plant Nutrition and Soil Science* 168:521–530.

Cuartero, J., Bolarin, M. C., Asins, M.J. and Moreno, V. 2006. Increasing salt tolerance in the tomato. *Journal of Experimental Botany* 57(5):1045-1058.

Dajic, Z. 2006. Salt Stres. *In*. K.V. M. Rao, A.S. Raghavendra and K. J. Reddy (eds). Physiology and Molekuler Biology Stress Tolerance in Plants. Springer. P. 41-99.

Dogar U.F., Naila, N., Maira, A., Iqra, A., Maryam, I., Khalid, H., Khalid, N., Ejaz, H.S. and Khizar, H.B. 2012. Noxious effects of NaCl salinity on plants. *Botany Research International* 5(1):20-23.

Erfandi, D. and Rachman, A. 2011. Identification of soil salinity due to seawater intrusion on rice field in the Northern Coast of Indramayu, West Java. *Journal of Tropical Soils* 16(2):115-121.

Eviati dan Sulaeman. 2009. Analisa kimia tanah, tanaman, air dan pupuk. Edisi ke-2. Balai Besar Litbang Sumberdaya Lahan Pertanian. Badan Litbang Pertanian. 246 p.

Fegeria, N.K. 2009. The Use of Nutrients in Crops Plants. CRC Press, Brazil. 430 P.

Gorham, J. 2007. Sodium. p. 569-575. *In* Barker, A.V. and D.J. Pilbeam (eds). Handbook of Plant Nutrition. Taylor & Francis. 613 pp.

Grattan, S.R. and Grieve, C.M. 1999. Salinity-mineral nutrient relations in horticultural crops. *Scientia Horticulturae* 78:127-157.

Hammad, S.A.R., Shaban, Kh. A. and Tantawy, M.F.2010. Studies on salinity tolerance of two peanut cultivars in relation to growth, leaf water content. Some chemical aspects and yield. *Journal of Applied Sciences Research* 6(10): 1517-1526.

Hirpara, KD., Prakash, J.R., Ashish, D.P. and Amar, N.P. 2005. Effect of salinisation of soil on growth and macro- and micro-nutrient accumulation in seedlings of *Butea monosperma* (Fabaceae). *Anales de Biologia* 27: 3-14

Hu Y. and Schmidhalter, U. 1997. Interactive effects of salinity and macronutrient level on wheat. 2. Composition. *Journal of Plant Nutrition* 20:1169–1182.

Hu, Y. and Schmidhalter, U. 2005. Drought and salinity: A comparison of their effects on mineral nutrition of plants. *Journal of Plant Nutrition and* Soil Science 168:541-549.

Iskandar, T and Chairunas. 2008. Palawija production in tsunami-affected soils in the Province of Nanggroe Aceh Darussalam. P. 109-113. *In* F. Agus and G. Tinning (eds). Proc. of Inter. Workshop on Post Tsunami Soil Manag. 180 pages.

Kitajima, K. and Fenner, M. 2000. Ecology of seedling regeneration. pp. 331-359. *In* M. Fenner (edt). Seeds: the ecology of regeneration in plant communities, 2nd ed. CABI Pub., Wallingford, UK.

Las, I., Subagyono, K. dan Setiyanto, A.P. 2006. Isu dan pengelolaan lingkungan dalam revitalisasi pertanian. *Jurnal Litbang Pertanian* 25(3):106-115.

Marwanto, S., Rachman, A., Erfandi, D. dan Subiksa, I.G.M. 2009. Tingkat salinitas tanah pada lahan sawah intensif di Kabupaten Indramayu, Jawa Barat. Hlm. 175-190. *Dalam* U. Kurnia, F. Agus, D. Setyorini, dan A. Setiyanto (eds). Pros. Sem. Nas. Multifungsi dan Konversi Lahan Pertanian. Balai Penelitian Tanah, Bogor.

Mudgal, V. 2004. Physiological studies on growth and nitrogen metabolism in *Cicer arietinum* L. under saline conditions. Ph.D. Thesis. Rohilkhand Univ., India.

Mungala, A.J., Radhakrishnan, T. and Junagadh, J.R.D. 2008. In vitro Screening of 123 Indian peanut cultivars for sodium chloride induced salinity tolerance. *World Journal of Agricultural Science* 4 (5): 574-582.

Nawaz, K., Khalid, H., Abdul, M., Farah, K., Shahid, A. and Kazim, A. 2010. Fatality of salt stress to plants: Morphological, physiological and biochemical aspects. review. *African Journal of Biotechnology* 9(34):5475-5480.

Nooghi, F.H. and Mozafari, V. 2012. Effects of calcium on eliminating the negative effects of salinity in pistachio (*Pistacia vera* L.) seedlings. *Australian Journal of Crop Science* 6(4):711-716.

Pessarakli, M. and Tucker, T.C. 1988. Dry matter yield and nitrogen-15 uptake by tomatoes under sodium chloride stress. *Journal of Soil Science Society of America* 52: 698-700.

Rachman, A., Subiksa, I.G.M., Erfandi, D. and Slavich, P. 2008. Dynamics of tsunami-affected soil properties. P 51-64. *In* F. Agus and G. Tinning (eds). Proc. of Inter. Workshop on Post Tsunami Soil Manag. 180 p.

Rogers, M.E., Grieve, C.M. and Shannon, M.C. 2003. Plant growth and ion relations in Lucerne (*Medicago sativa* L.) in response to the combined effects of NaCl and P. *Plant and Soil* 253: 187-194.

Sembiring, H., Gani, A. and T. Iskandar, I. 2008. Implications of salinity research in Aceh for indonesian rice growing. P. 97-108. *In* F. Agus and G. Tinning (eds). Proc. of Inter. Workshop on Post Tsunami Soil Manag. 180 pages.

Shukla, P.S., Agarwal, P.K. and Jha, B. 2010. Improved salinity tolerance of *Arachis hypogaea* (L.) by the interaction of halotolerant plant-growth-promoting rhizobacteria. *Journal of Plant Growth Regulation* 31:195–206.

Singh, A.L., Hariprassana, K. and Solanki, R.M. 2008. Screening and selection of groundnut genotypes for tolerance of soil salinity. *Australian Journal of Crop Science* 1(3):69-77.

Sonon, L.S., Saha, U. and Kissel, D.E. 2015. Soil Salinity: Testing, data interpretation and recommendations. UGA Cooperative Extention Circular 1019, Univ. of Georgia. 6 pages.

Sposito, G. 2008. The Chemistry of Soil. Oxford University Press, New York. 321 pp.

Suganda, H., Setyorini, D., Kusnadi, H., Saripin, I. dan Kurnia, U 2009. Evaluasi pencemaran limbah industri tekstil untuk kelestarian lahan sawah. Hlm. 203-221. *Dalam* U. Kurnia, F. Agus, D. Setyorini, dan A. Setiyanto (eds). Pros. Sem. Nas. Multifungsi dan Konversi Lahan Pertanian. Balai Penelitian Tanah, Bogor.

Taffouo, V.D., Wamba, O.F., Youmbi, E., Nono, G.V. and Akoa, A. 2010. Growth, yield, water status and ionic distribution response of three bambara groundnut (*Vigna subterranean* (L.) Verdc.) landraces grown under saline conditions. *International Journal of Botany* 6:53-58.

Taufiq, A., Kristiono, A. dan Harnowo, D. 2015. Respon varietas unggul kacang tanah terhadap cekaman salinitas. *Jurnal Penelitian Pertanian Tanaman Pangan* 34(2):153-164.

Tester, M. and Davenport, R. 2003. Na^+ tolerance and Na^+ transport in higher plants. *Annals of Botany* 91:503-527.

White, P.J. and Broadley,M.R. 2001. Chloride in soils and its uptake and movement within the plant: a review. *Annals of Botany* 88: 967-988.

Yadav, S., Mohammad, I., Aqi, A. and Shamsul, H. 2011. Causes of salinity and plant manifestations to salt stress: a review. *Journal Environmental Biology* 32: 667-685.

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