

Research Article

Effect of mulching and amelioration on growth and yield of groundnut on saline soil

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Abstract: Agricultural lands affected by salt facing complex problems associated with soil salinity and the toxicity effects of Na cation. Soil amelioration and mulching is an alternative to alleviate negative effect of salinity. Objective of research was to identify effective ameliorant, and effect of mulching in improving growth and yield of groundnut on saline soil. The research had been conducted on saline soil (soil EC 12 dS/m) in Lamongan during dry season of 2016, using Hypoma 2 cultivar. Treatments that consisted of two factors were arranged in a split plot design with three replicates. The main plot was mulching (without mulching and mulching with 3.5 t/ha of rice straw), and the sub plot was soil ameliorations (control, 120 kg/ha K₂O, 750 kg/ha S, 5 t/ha gypsum, 5 t/ha manure, and 1.5 t/ha of gypsum + 5 t/ha manure). Results showed that mulching, and amelioration with 120 kg/ha K₂O, 750 kg/ha S, 5 t/ha gypsum decreased soil EC, but could not improve groundnut growth and could not retard chlorophyll degradation because the soil was EC still high (12.5 dS/m). The higher yield (1.49 t/ha dry pods) can be obtained by amelioration with 750 kg sulphur/ha combined with mulching.

Keywords: *amelioration, groundnut, mulching, salinity*

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Introduction

Salt affected of agricultural land in coastal area tend to increase due to sea water intrusion (Marwanto et al., 2009; Erfandi and Rachman, 2011), intensive use of irrigation from deep well (Wanget al., 2008; Putra and Indradewa, 2011), and natural dissaster like tsunami (Rachman et al., 2008; Royet al. 2014). Increasing soil salinity raising complexes problem, including high Na concentration (Tester and Davenport, 2003) and Cl (Papadakis et al., 2007) in the soil, that is difficult to overcome. Salinity affects plant growth in all growing stage (Nawaz et al., 2010), reduces water absorption by crop (Kronzucker et al., 2006; Salwa et al., 2010), reduces nutrient uptake (Salwa et al., 2010; Jouyban, 2012), and chlorophyll content (Xing et al., 2013; Nokandeh et al., 2015). Salinity tolerance of groundnut

varied among genotypes (Singh et al. 2007; Singh et al. 2008). Taufiq et al. (2015) found that pod yield of 10 cultivars decreased by 30-53% at salinity of 1.60-1.84 dS/m and by 59-93% at salinity of 2.95-4.44 dS/m compared to the control. At low salinity level, planting tolerant cultivar is more efficient than amelioration. However, amelioration is needed if the salinity above the level that can be tolerated by crop. Leaching is the most effective method to reduce soil salinity, but it need much fresh water and time consuming. An alternative way is alleviating negative effect of Na. Soil EC can be reduced and negative effect of Na can be alleviated by application of K (Kabir et al., 2004; Kopittke, 2012), Ca (Dabuxilatu and Ikeda, 2005), and elemental S (Nazar et al., 2011). Application of compost (Radwan and Awad, 2002), gypsum

(Niazi et al., 2007; da Silveira et al., 2008; Joachim and Verplancke, 2010), combination of manure with gypsum (Smith et al., 2009; Chaum et al., 2011; Kahlon et al., 2012; Murtaza et al., 2013) are effective in decreasing soil EC and improving plant growth. Application of P and K fertilizer, manure, ash, and dolomite increased yield of rice and palawija crops on saline soil (Sembiring et al., 2008; Iskandar and Chairunas, 2008). Mulching effective in alleviating salinity effect (Dong, 2012). Mulching reduced salt accumulation under high saline irrigation (Zang et al. 2008), and decreased soil salinity (Abou-Baker et al. 2011). Alharbi (2015) showed that mulching decreased soil salinity of surface layers compared to the unmulched layer. Objective of the research was to identify the effective ameliorant and effect of mulching in improving growth and yield of groundnut on saline soil.

Materials and Methods

The research was conducted at Lohgung Village, Berondong Sub District, Lamongan District (6°53'59.89801" S; 112°11'15.31277" E; 26 m above sea level) from May to August 2016. The experimental site is about 1.5 km from the coast, and the soil at the trial site developed from lime stone. Soil salinity as indicated by soil EC is high, soil pH is mildly alkaline. Cation saturation at exchange site dominated by Ca (56.5%) and Mg (35.1%), while K and Na only 2.4% and 6.0%, consecutively (Table 1). Based on soil EC (>4 dS/m), pH (<8.5), and exchangeable sodium percentage (<15%) indicate that the soil at experimental site is classified as saline soil. Soil at the site is highly saline because the EC in the range of 8.8-16.0 dS/m according to Jones (2002). According to Hazelton and Murphy (2007), the soil contain high K, very high Ca, Mg, and Na. Treatments that consisted of two factors were arranged in a split-plot design with three replicates. The main plot was two levels of mulching, consisted of without mulch (M0) and mulching with 3.5 t/ha of rice straw (M1). The sub plot was six soil ameliorations consisted of control (A0), 120 kg/ha K₂O (A1), 750 kg/ha Sulphur (A2), 5 t/ha gypsum (A3), 5 t/ha cow manure (A4), and 1.5 t/ha gypsum+5 t/ha cow manure (A5).

Ameliorant treatment applied just before planting, while mulching treatment applied just after planting. Rice straw of the previous crop cleared from the land. Paraquate dichloride herbicide sprayed before planting to control weeds, and the land cultivated using rotary at one week after weed control. Before planting,

groundnut seed of Hypoma-2 cultivar treated with insecticide of active ingredient the ametoaxam. The seeds were planted in the plot of 4 m x 3 m with plant spacing of 40 cm x 15 cm, 1-2 seeds/hole. Irrigation from adjacent well with water-EC of 3.88 dS/m applied just after planting. The rain often fall at the site from 15 days after planting (DAP) up to harvest, and so that no more irrigation added. Weeding conducted twice, at 15 DAP using propaquizofap herbicide, and manual weeding at 45 DAP together with ridging. Basal fertilization at rates of 36 kg P₂O₅/ha and 30 kg K₂O/ha broadcasted just after planting, while 33.7 kg N/ha applied at 15 DAP. Pest was controlled regularly using fipronil, deltamethrin, chlorantraniliprol, and pyridaben insecticide accordingly.

Table 1. Soil properties in the top 0-20 cm at experimental site.

Parameters	Method	Value
pH-H ₂ O	1:5	7.8
EC (dS/m)	Field measurement ¹⁾	12.10
C-organic (%)	Walky-Black	1.02
Exch-K (cmol ⁺ /kg) ²⁾	NH ₄ OAc pH 7	1.00
Exch-Na (cmol ⁺ /kg)	NH ₄ OAc pH 7	2.51
Exch-Ca (cmol ⁺ /kg)	NH ₄ OAc pH 7	23.7
Exch-Mg (cmol ⁺ /kg)	NH ₄ OAc pH 7	14.7
CEC (cmol ⁺ /kg)	Cation summation	41.91
Na saturation (%)	(Exch-Na/CEC)*100	5.99

¹⁾using Hanna portable EC meter type HI993310; ²⁾exch=exchangeable

Observation consisted of soil analysis at harvest (pH, C-organic, exchangeable Na, Ca, Mg, and K). Electrolic conductivity (EC, using Hanna portable EC meter type HI993310) and soil water content at 0-20 cm of soil depth (gravimetric method) were measured every 15 days from planting up to 75 DAP. Tissue analysis of shoot (Na, Ca, Mg, and K) was measured at pegging stage. Four samples collected from each plot were oven dried at 75°C up to constant weight and then ground and composited according to the treatments during grinding. Soil and plant analyses were conducted at Iletri's Laboratory according to Eviati and Sulaeman (2009). Agronomic parameters consisted of number of seedling at 15 DAP, shoot dry weight at pegging stage, plant height and chlorophyll content index at 15, 30, 45, 60 and 75 DAP. Chlorophyll content

index was measured using Chlorophyll meter SPAD-500. Observation at harvest consisted of number of harvested plant, number of filled pods, pod and kernel weight. Variance analysis used to detect effect of treatments, and mean comparison using Least Significant Different (LSD) at 5% level of significance.

Results and Discussion

Soil properties and nutrient uptake

Mulching treatment tended to reduce soil EC at all observation dates with reduction varied from 0.22 to 1.34 dS/m (Figure 1). The differences of EC between mulching and unmulching treatment was

not significantly difference, except at 60 DAP and 75 DAP. Mulching treatment did not significantly affect soil moisture content, even the soil moisture tend to be higher than without mulching (Figure 1). The soil EC fluctuated between observation, and it tended to increase as soil moisture decreased. Mulching reduce evapotranspiration and salt accumulation (Zhang et al., 2008), maintain moisture content in the root zone, and also reduce soil temperature, evaporation and salt accumulation (Abou-Baker et al., 2011; Swarup, 2013; Alharbi, 2015). Reduction of soil EC in this experiment might be due to reduction of salt accumulation in the top soil layer.

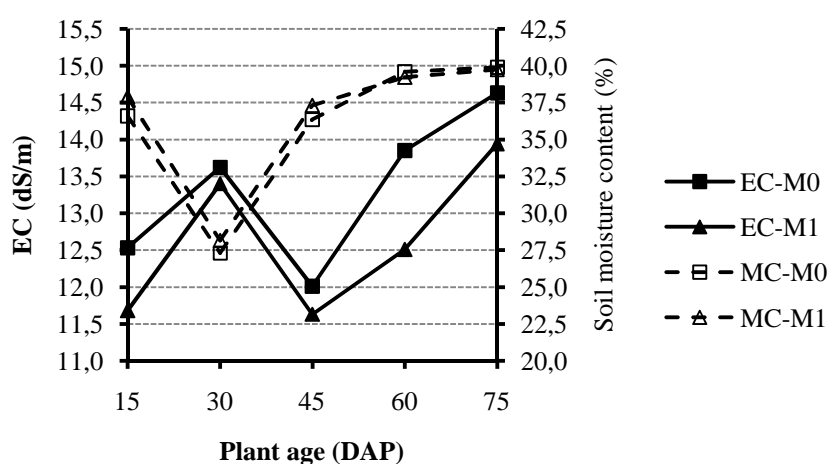


Figure 1. Effect of mulching on soil EC and soil moisture content at 15 DAP up to 75 DAP on saline soil. Lamongan, dry season 2016. (M0=without mulch, M1=with mulch, EC=electrolic conductivity, MC=moisture content)

Soil amelioration with 120 kg/ha K_2O , 750 kg/ha S, 5 t/ha gypsum, 5 t/ha manure, and 1.5 t/ha gypsum+5 t/ha manure affected soil EC, but the differences was statistically not significant (Figure 2A). The dynamic of soil EC due to amelioration seemed more related to the dynamic of soil moisture content (Figure 2B). Soil EC during the trial was >11 dS/m, and it was above the critical level of 3.2 dS/m (Yadav et al., 2011). In pot experiment, groundnut could not perform pod on soil EC 6.5 dS/m (Mungala et al., 2008), on soil EC >1.84 dS/m (Taufiq et al., 2015). On field experiment with soil EC 15.33 dS/m, groundnut of Domba and Hypoma-1 cultivar produced 0.5-0.7 t/ha dry pod (Taufiq et al., 2016). Mulching and amelioration treatments and their interaction had no significant affect on soil pH, C-organic content, exchangeable K (exch-K), Ca, Mg, and Na (Figures 3 and 4). Exch-Na in all treatments was less than 0.3 cmol/kg, and was classified as

low according to Hazelton and Murphy (2007). Soil pH at harvest was 0.7 units higher than at planting (increased from 7.8 to 8.5), that might be due to salt accumulation on top soil layer as indicated by increasing soil EC. Soil EC was significantly affected ($p=0.05$) by intercation between mulching and amelioration treatments. All amelioration treatments, except manure, combined with mulching resulted lower EC than without mulching (Figure 4C). Mulching had positive effect on the EC reduction. Without mulching, soil EC increased linearly) as soil depth decreased from 12 cm to 9 cm, 6 cm and 3 cm ($Y=16,985-0,6589X$, $R^2 =0,99$). With mulching, soil EC at 3 cm and 6 cm was relatively similar, and then it decreased up to 12 cm of soil depth (Figure 4D). This data indicated that mulching retarded salt accumulation and increasing of EC in the top soil layer. As reported by Abou-Baker et al. (2011) and Swarup (2013) that mulching

reduce soil temperature and evaporation. Decreasing of soil temperature and evaporation will reduce the flow rate of dissolve salt in the soil from the deeper layer to the top layer, and hence retard salt accumulation in the top layer. Uptake of K, Na, Ca, and Mg due to amelioration treatments were lower than control (Figure 5). Among the ameliorants, application of 750 kg S/ha or 5 t/ha manure increased uptake of K, Na,

Ca and Mg, but application of 120 kg K_2O /ha or with 5 t/ha gypsum decreased K, Na, Ca, and Mg. Uptake of Na was higher if amelioration with K_2O or gypsum was combined with mulching (Figure 4). This means, that amelioration of saline soil with K_2O or gypsum is better than with sulphur (S) or manure or combination of manure and gypsum, and the effect is better if combined with mulching.

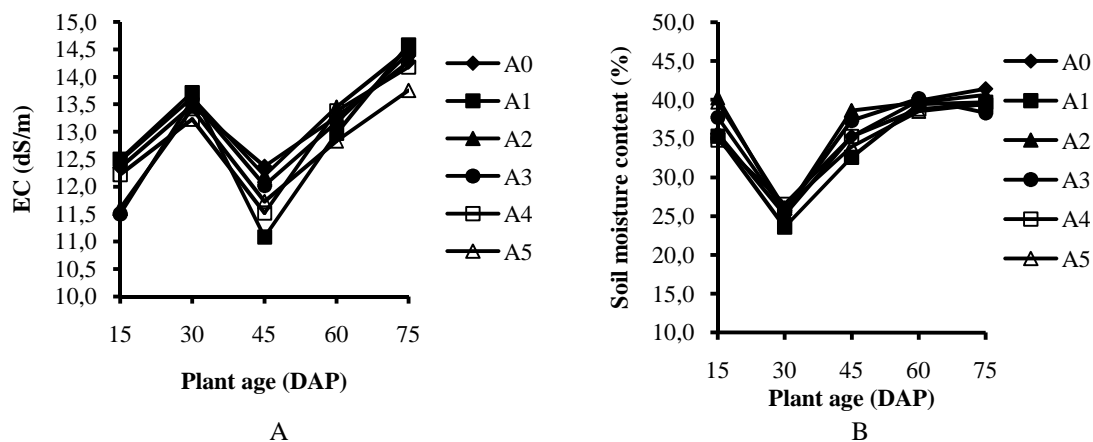


Figure 2. Effect of ameliorant on soil EC (A) and soil moisture content (B) at 15 DAP up to 75 DAP on saline soil in Lamongan during dry season 2016. (A0=control, A1=120 kg/ha K_2O , A2=750 kg/ha S, A3=5 t/ha gypsum, A4=5 t/ha manure, A5=1.5 t/ha gypsum+5 t/ha manure)

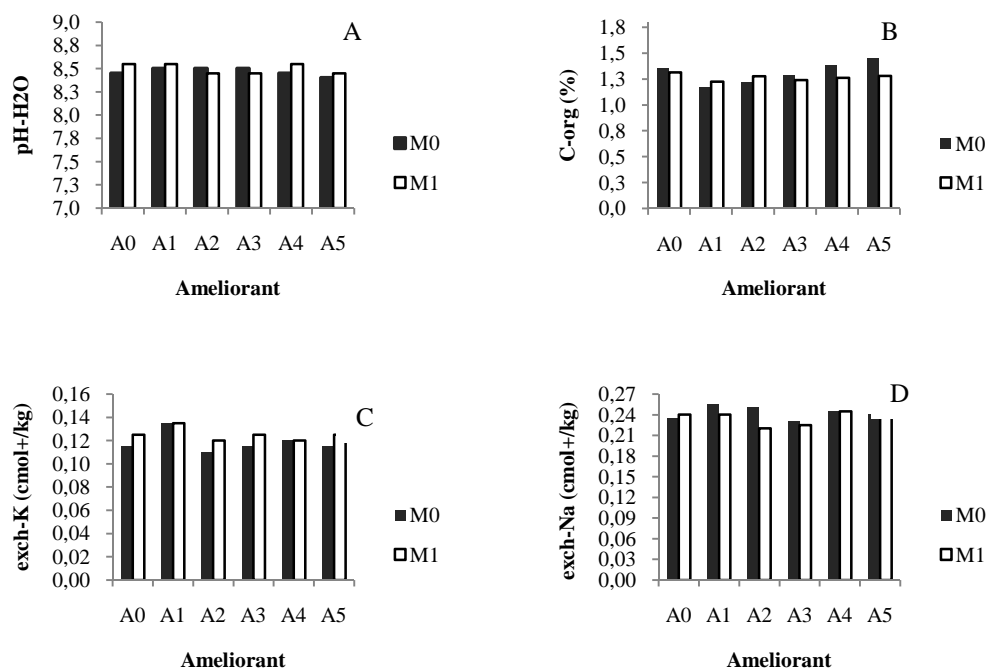


Figure 3. Effect of ameliorant and mulching on soil pH, C-organic, exch-K, and exch-Na on saline soil in Lamongan during dry season 2016. (M0=without mulch, M1=with mulch, A0=control, A1=120 kg/ha K_2O , A2=750 kg/ha S, A3=5 t/ha gypsum, A4=5 t/ha manure, A5=1.5 t/ha gypsum+5 t/ha manure)

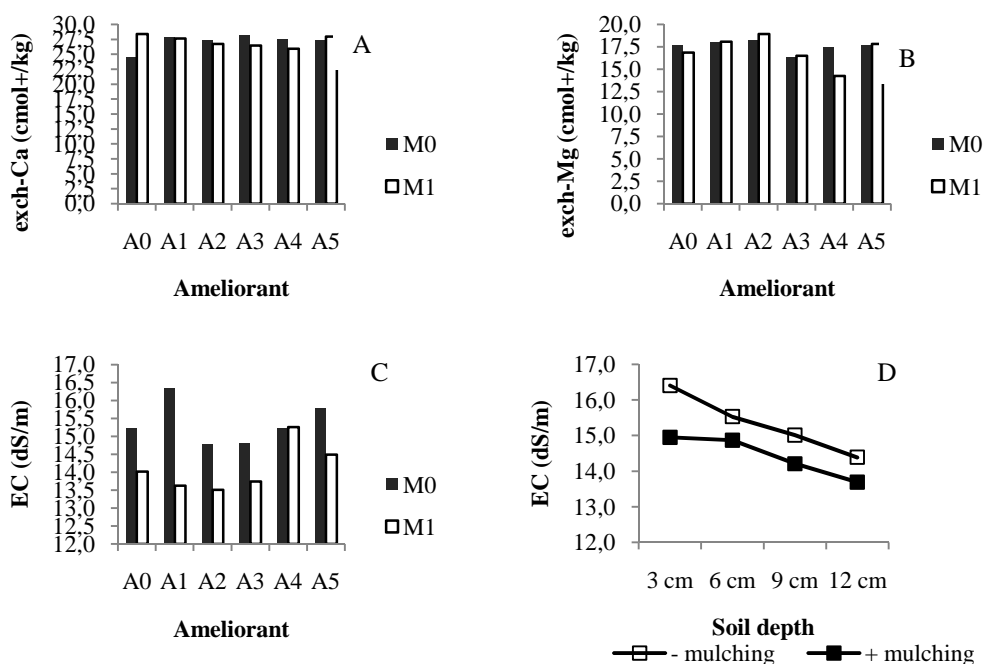


Figure 3. Effect of ameliorant and mulching on exch-Ca, exch-Mg, and EC on saline soil in Lamongan during dry season 2016. (M0=without mulch, M1=with mulch, A0=control, A1=120 kg/ha K₂O, A2=750 kg/ha S, A3=5 t/ha gypsum, A4=5 t/ha manure, A5=1.5 t/ha gypsum+5 t/ha manure)

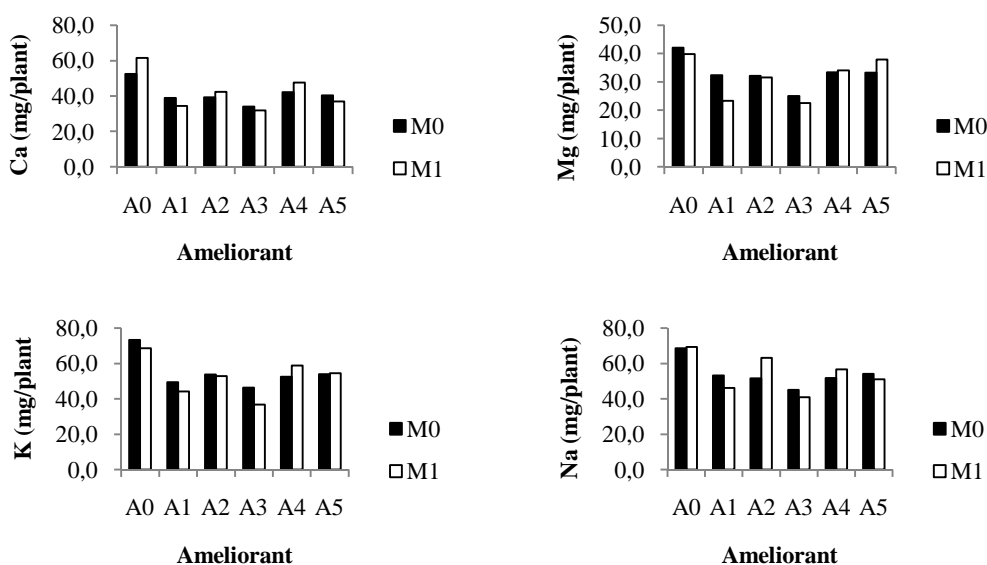


Figure 5. Effect of mulching and ameliorant on K, Ca, Na, and Mg uptake of groundnut of Hypoma 2 cultivar at pagging stage on saline soil in Lamongan, during dry season year 2016. (M0=without mulch, M1=with mulch 3.5 t/ha; A0=control, A1=120 kg/ha K₂O, A2=750 kg/ha S, A3=5 t/ha gypsum, A4=5 t/ha manure, A5=1.5 t/ha gypsum+5 t/ha manure)

The results indicated that mulching effectively reduce soil EC in the top soil layer, but could not reduce Na uptake by groundnut. Amelioration

with K₂O, sulphur and gypsum combined with mulching effectively reduced EC, but had no effect on exch-Na.

Plant growth

The seed of Hypoma-2 cultivar started to germinate at 5 DAP. Plant vigor at germination stage was good even though the soil EC 12.10 dS/m. Germination percentage at 10 DAP was 95-98%, and plant population at harvest was 87.6%. Mulching treatment significantly improved plant

height at 30DAP up to 75 DAP, but not significantly affected shoot biomass at 55 DAP (maximum vegetative stage) and at harvest. Amelioration treatments did not improve plant growth as indicated by plant height and shoot biomass at all observation date, except shoot biomass at 55 DAP where amelioration reduced the biomass compared to control (Table 2).

Table 2. Effect of mulching and amelioration on plant height and shoot biomass of groundnut on saline soil in Lamongan on dry season 2016.

Treatment	Plant height (cm)					Shoot biomass		
	15 DAP	30 DAP	45 DAP	60 DAP	75 DAP	At harvest	55 DAP (g/5 plants)	At harvest (t/ha)
Mulching								
Without mulch	4.1 a	6.5b	11.6 b	19.5b	21.5 b	25.6	15.68	2.06
With mulch	3.4 b	8.0a	12.8 a	21.5a	23.0 a	25.9	15.31	2.18
Amelioration								
Control	3.8	7.2	12.1a	19.9	21.8	25.1	19.88a	2.04
120 kg/ha K ₂ O	3.7	6.7	12.2a	21.0	22.0	25.5	13.56b	2.15
750 kg/ha S	3.8	7.6	12.3a	21.3	22.7	26.0	15.22b	2.29
5 t/ha gypsum (G)	3.8	7.3	10.9b	19.0	20.9	25.3	12.67b	2.23
5 t/ha manure(M)	3.7	7.4	13.0a	21.0	22.7	25.4	16.47ab	2.03
1.5 t/ha G+5 t/ha M	3.9	7.2	12.7a	20.9	23.5	27.0	15.17b	1.97
CV (%)	6.63	7.52	7.62	7.86	8.84	5.16	23.02	17.04

Numbers in the same column in each main factor with the same letter or without letter means not significantly different with LSD 5%. DAP = days after planting.

Mulching and amelioration treatments and their interaction had no significant effect on chlorophyll content index (CCI). CCI value continuously reduced with plant age increased (Figure 6). It means that chlorophyll content reduced and leaves become more yellowish. Figure 7 illustrates the relationship between CCI value and leaf colour. Mulching and amelioration treatments could not retard chlorophyll degradation. Even though mulching and amelioration treatments significantly decreased soil EC, they but had no positive effect on CCI because the soil EC was still high (ranged from 11 dS/m to 15 dS/m). Reduction of chlorophyll content due to salinity stress also reported by Hossain et al. (2011), Xing et al. (2013) and Nokandeh et al. (2015).

Yield and yield components

Rice straw mulching increased number of branches and number of filled pods, but no significant effect on weight of fresh and dry pod, weight of dry kernel, weight of 100 kernels, harvest index and kernel to pod weight ratio. Amelioration and its interaction with mulching

had no significant effect on these variables, except on weight of dry pod and dry kernel (Table 3). Soil EC at trial site was very high, and groundnut only performed 6-7 pods/plant. Mensah et al. (2006) found that number of filled pod decreased with increasing soil EC, from 11-17 pods/plant at EC ≤4.68 dS/m to 7 and 6 pods/plant consecutively at EC 8.9 dS/m and 17 dS/m. Seed size of Hypoma-2 cultivar on saline soil was bigger than on non saline soil, as indicated by weight of 100 kernels of 34.2-36.2 g on saline soil (Table 3), and about 31.2 g on non saline soil (based on the cultivar description). Ratio of kernel to pod on saline soil was lower (0.35-0.40) than on non saline soil (0.60-0.70). Mulching and amelioration treatments did not increase pod and kernel weight. Hypoma-2 cultivar yielded 3 t/ha of fresh pod (1.3 t/ha dry pod), 0.49 t/ha dry kernel (Table 3). Potential yield of Hypoma-2 cultivar on non saline soil is 3.2 t/ha dry pod. It means that the yield of 1.3 t/ha dry pod on saline soil with EC 11-15 dS/m is about 41% of yield on non saline soil. Harvest index (HI) value in this experiment was 0.38, in the range of common HI of groundnut (0.3-0.5).

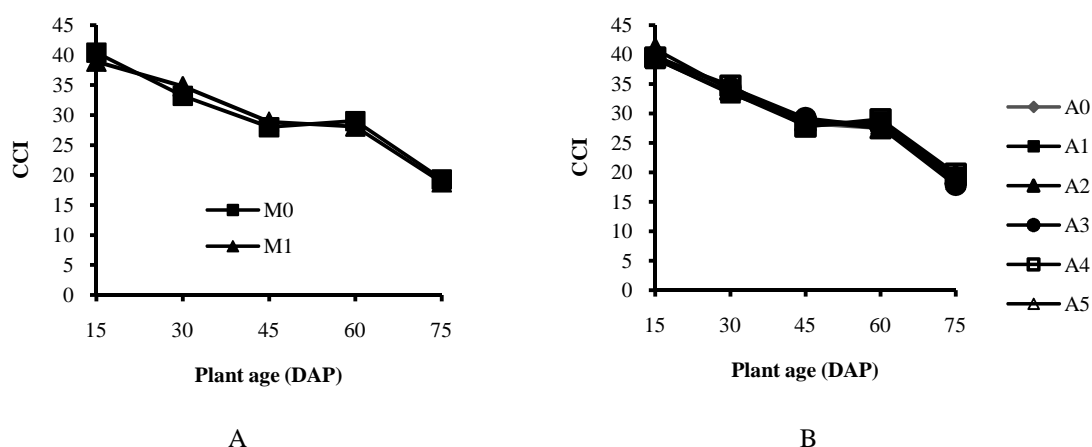


Figure 6. Effect of mulching (A) and ameliorant (B) on chlorophyll content index (CCI) of groundnut leaf from 15 DAP up to 75 DAP on saline soil in Lamongan during dry season 2016. (M0=without mulch, M1=with mulch 3.5 t/ha; A0=control, A1=120 kg/ha K₂O, A2=750 kg/ha S, A3=5 t/ha gypsum, A4=5 t/ha manure, A5=1.5 t/ha gypsum+5 t/ha manure)

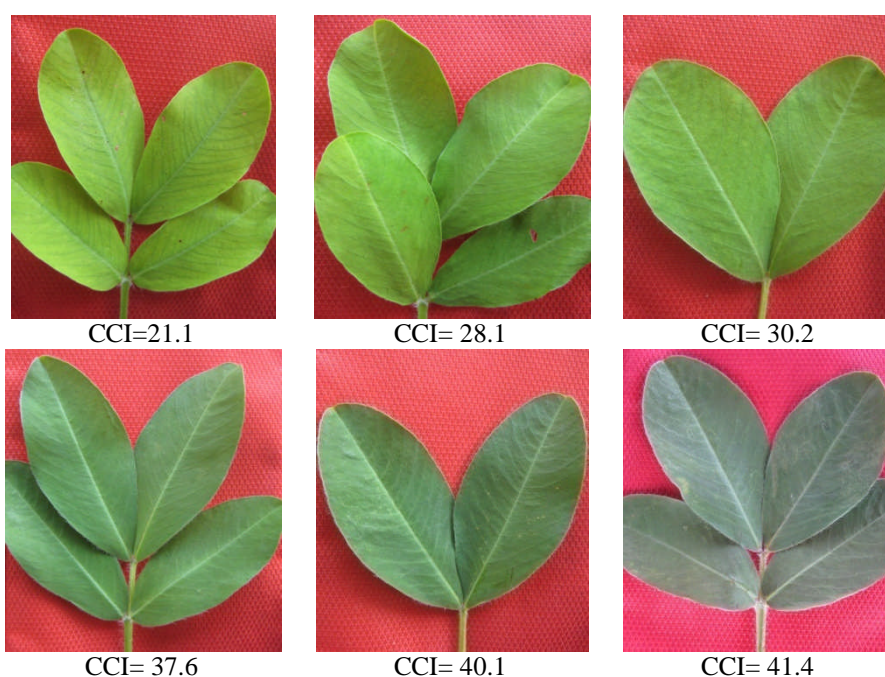


Figure 7. Illustration of relationship between chlorophyll content index (CCI) and leaf colour.

Pod and kernel weight were significantly affected by interaction between mulching and amelioration treatment. The highest pod yield (1.49 t/ha) was obtained by amelioration with 750 kg S/ha combined with mulch (Table 4). Amelioration with gypsum or gypsum+manure decreased pod yield if combined with mulch treatment. It means that pod yield of groundnut on saline soil can be increased by amelioration with 750 kg S/ha

combined with mulching. The highest kernel weight (0.61 t/ha) was obtained by amelioration with 5 t/ha manure without mulch, or by amelioration with 120 kg K₂O/ha combined with mulch (Table 4). This indicates that the kernel yield of groundnut on saline soil can be increased by amelioration with 5 t/ha manure, or by amelioration with 120 kg K₂O/ha combined with mulch.

Table 3. Effect of mulching and amelioration to the yield and yield components of Hypoma-2 cultivar on saline soil in Lamongan indry season 2016.

Treatment	No. of Branches	No. of Filled pods	Fresh pod weight (t/ha)	Dry pod weight (t/ha)	Dry kernel weight (t/ha)	Harvest index	Weight of 100 kernels (g)	Kernel to pod ratio
Mulching								
Without mulch	4b	6b	2.97	1.31	0.49	0.38	35.57	0.38
With mulch	5a	7a	3.12	1.28	0.49	0.37	34.40	0.37
Amelioration								
Control	4	6	3.05	1.44	0.54	0.40	34.92	0.37
120 kg/ha K ₂ O	5	7	3.12	1.36	0.53	0.37	34.37	0.39
750 kg/ha S	5	7	3.23	1.33	0.48	0.37	36.25	0.35
5 t/ha gypsum (G)	4	7	2.88	1.21	0.45	0.35	34.22	0.37
5 t/ha manure (M)	5	7	2.99	1.28	0.51	0.38	34.55	0.38
1.5 t/ha G+5 t/ha M	4	7	3.99	1.16	0.45	0.39	35.62	0.40
CV (%)	7.94	12.50	18.42	14.10	17.99	9.78	11.69	7.94

Numbers in the same coloum in each main factor with the same letters or without letters mean not significantly different with LSD 5%.

Table 4. Effect of mulching and amelioration on yield of groundnut of Hypoma 2 cultivar on saline soil in Lamongan, dry season year 2016.

Amelioration	Pod weight (t/ha)		Kernel weight (t/ha)	
	Without mulch	With mulch	Without mulch	With mulch
Control	1.43 ab	1.44 ab	0.50 abcde	0.57 ab
120 kg/ha K ₂ O	1.34 ab	1.39 ab	0.46 abcde	0.60 a
750 kg/ha S	1.16 bc	1.49 a	0.40 bc	0.56 abc
5 t/ha gypsum (G)	1.27 abc	1.16 bc	0.47 abc	0.43 bc
5 t/ha manure (M)	1.36 ab	1.21 abc	0.61 a	0.41cde
1.5 t/ha G+5 t/ha M	1.34 ab	0.99 c	0.54 abcd	0.37 e

Numbers in the same variable with the same letters meannot significantly different with LSD 5%.

Conclusion

Mulching using 3.5 t/ha rice straw and amelioration with 120 kg/ha K₂O, 750 kg/ha S, 5 t/ha gypsum decreased soil EC. However, mulching was more effective in reducing soil EC than amelioration with K₂O, S, and gypsum. Even though mulching decreased soil EC by 0.22-1.34 dS/m, but it could not improve groundnut growth and could not retard chlorophyll degradation because the soil EC still high (12.5 dS/m). The higher yield (1.49 t/ha dry pods) could be obtained by amelioration using 750 kg sulphur/ha combined with mulching.

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