The Growth Response Variability of Some Legume Species on Salinity

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Abstract. Abundant amount of saline soils provides possibility to increase farming acreage in Indonesia. Legume species are good sources of protein for Indonesian daily food. Among legumes species, some species could show more tolerant to salinity and could be potentially cultivated on saline soils. Our present research work was undertaken to evaluate the growth response of legume species to salinity. Alfisol and saline soils, as main factors, used in the study were combined factorially with six legume species (groundnut, soybean, pigeon pea, velvet bean, hyacinth bean and sword bean) as sub-factor. Each factorial treatment was arranged in randomized block designed and was replicated three times. The standard deviation (SD) analysis was used to analyse the effect of salinity to the growth of legume species. Plant height at 15 days after sowing (DAS) and at 50 DAS, shoot diameter at 50 DAS, root dry weight at 50 DAS, shoot dry weight at 50 DAS and leaf dry weight at 50 DAS varied among legume species on Alfisol and saline soils. In general, the plant growth of legume crops, measured as plant height, plant diameter, root dry weight, shoot dry weight and leaf dry weight, was significantly retarded by salinity at different degree. The growth reduction on saline soil was related to higher Na concentration in roots and leaves. The highest and the lowest degrees of retardation by salinity on root, shoot and leaf dry weights were observed on pigeon pea and groundnut, respectively. Soybean, velvet bean, and hyacinth bean showed the degree of growth retardation by salinity between pigeon pea and groundnut. Response to salinity of sword bean was comparable to groundnut. Thus, groundnut and sword bean could be cultivated on saline soil.
Keywords: Legume crops, Alfisol soil, saline soil, growth retardation

1 Introduction

Seeds of legumes are known as daily important food sources by Indonesian people. These legumes contained high protein (1, 2, 3, 4, 5, 6) and were considered to be a good alternative food source consequently (4, 7, 8). Besides, the seeds of legumes were revealed to contain molecules playing important role as an antioxidant (9). The legume seeds were consumed in different forms of food products which were previously processed in various ways (10, 11, 12, 13, 14, 15, 16).

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Legumes as secondary food crops are generally cultivated on less fertile soils, like upland soils. Saline soils could also possibly be used for growing legumes since saline soils are abundantly available in Indonesia. Indonesia consists of many islands and each island is surrounded by sea. The sea water will daily infiltrate the agricultural land near the seashore. The sea water infiltration would definitely create saline environment to the soils. Therefore, agricultural saline soils would be established in Indonesia in a large amount. Taufiq et al. (17) and Soedarjo et al. (18) reported that agricultural soils near the seashore in East Java was characterized with high salinity. Possible usage of saline soils for farming would play important role for food sustainability.

However, saline soils have been known unfavorable for cultivating some crop species. The growth of soybean, ground nut and rice are revealed to be deleteriously affected by salinity (19, 20; 21, 22). Konjac (*Amorphophallus muelleri* Blume) plants grown on saline soil underwent severe growth retardation and failed to form corms (18). It was assumed that susceptibility to salinity was regulated genetically. The assumption was based on the research findings by Mindari et al. (23) and Raza et al. (24) who showed different response of maize genotypes to salinity. The variability in salinity response within the varieties of some rice was also reported by Kurniawan et al. (25). Our present research work was undertaken to investigate the growth response of some legume species on saline soil.

2 Materials and methods

2.1 Soil preparation

Alfisol and saline soils used in the present study as well as the soil preparation were the same as used for evaluation of porang response to salinity (18). Alfisol soil was characterized as fertile soil and porang grew normally (18, 26). Saline soil was characterized as soil with lower chemical fertility compared to Alfisol soil and contained high Na (sodium) was considered as unfavorable soil for cultivating some plants. Plants grown on this saline soil experienced severe toxicity symptoms and growth retardation (18, 26). Polyethylene pot was filled with 5 kg of air-dried Alfisol or saline soil. Water addition to make up water field capacity before sowing the seeds and water addition during the growing period followed the method previously described (18).

2.2 Plant sowing and plant caring

The seeds of groundnut, soybean, pigeon pean, velvet bean, hyacinth bean and sword bean were selected to obtain uniform (seed size and seed coat color for each legume species) and and healthy seeds (free frommdisease). Two-three seeds of each legume were sown in previously made hole of each bag. At 5 days after sowing (DAS), the seedlings were thinned and kept to one healthy seedling during the study. The plant caring, i.e., watering, weeding and pest control, was done appropriately to keep the plants growing healthily.

2.3 Experimental design

The present study was done in the campus of Indonesian Legume and Tuber Crops Research Institute (ILeTRI) from May to June 2021. The study site was located at an altitude of 500 m above sea level (medium altitude). The study examined the growth response of some legume species (G-1, G-2, G-3, G-4, G-5, G-6= Groundnut, soybean,

pigeon pea, velvet bean, hyacinth bean and sword bean). Legumes were grown on Alfisol and saline soil as growing environment. Each of the legume species, as treatment, was laid out in randomized block design and was replicated 3 times. The growth response of legumes on Alfisol and saline soils was evaluated by measuring the plant height at 15 DAS and 50 DAS, plant diameter at 15 DAS and 50 DAS, root dry weight, shoot dry weight and leaf dry weight at harvest (50 DAS). Measurement method described by Soedarjo (26) was employed. Each data obtained was analyzed by using Standard Deviation (SD) from 3 replicates. Plant sample from each treatment was analyzed chemically in Plant and Soil Laboratory of ILeTRI (ISO/IEC 17025-2017) to measure total N, total P and Na concentration.

3 Results and discussion

3.1 Plant nutrient analysis

Total N, P and Na concentration in roots and in leaves of legumes grown on Alfisol soil and on saline soil (Figs. 1A, 1B, 1C, 1D, 1E and 1F) varied among the legume species, indicating that the genetic of legume species influenced the difference in N, P and Na absorption. Standard deviation analysis showed that total N and P of roots and leaves was significantly higher in each legume species when grown on Alfisol soil than on saline soil. This result suggests significantly higher absorption of N and P in legumes at Alfisol soil than at saline soil. However, Na concentration in roots and leaves was found to be significantly lower on Alfisol soil than on saline soil. Thus, higher Na in roots and in leaves might prevent N and P absorption by legumes on saline soil. Additionally, higher available N and P in Alfisol soil (18) could result in higher absorption of N and P in leaves of legumes leading to higher total N and P in roots and leaves. Significant decrease of N and P in *Tetragonia decumbens* Mill when exposed to saline environment was also reported elsewhere (24).

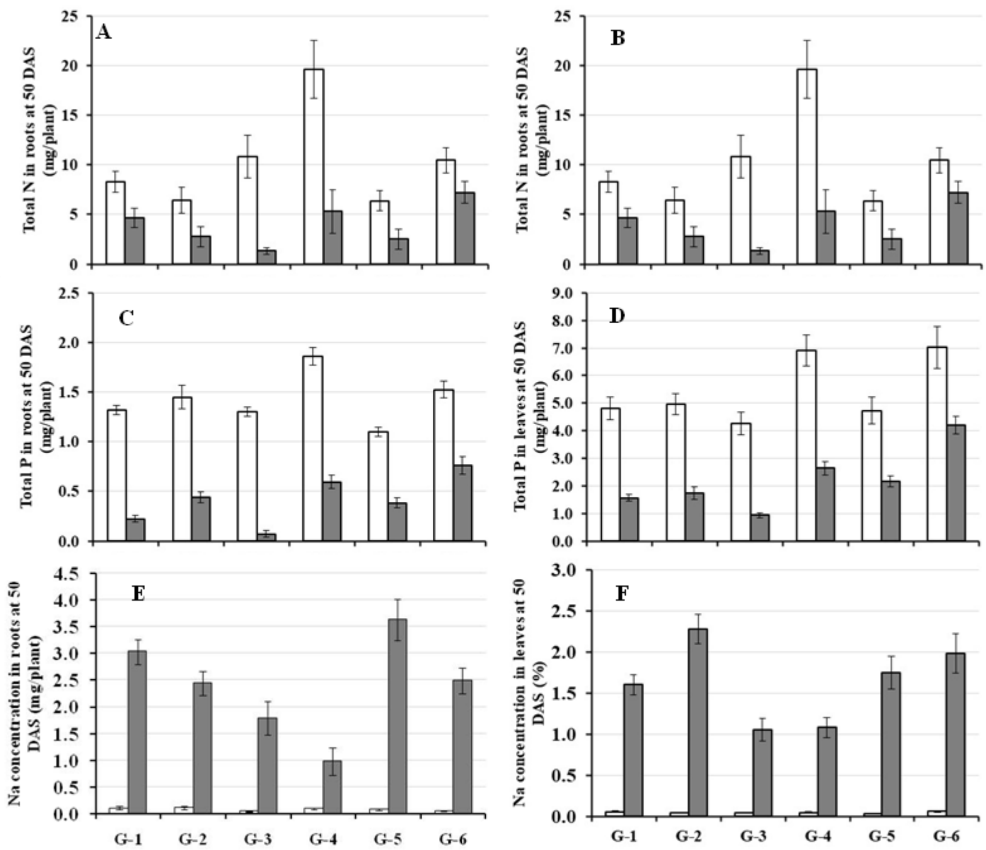

Fig. 1. Effect of salinity on plant nutrient of legume crops at 50 DAS. Empty and solid bars are Alfisol and saline soils. G-1, G-2, G-3, G-4, G-5 and G-6 on X axis are groundnut, soybean, pigeon pea, velvet bean, hyacinth bean and sword bean.

3.2 Plant growth performances on Alfisol and saline soils

All legume species grown on Alfisol soil showed normal growth. In contrary, the worse growth performances as clearly indicated by lower plant height was observed when the legume species were planted on saline soil (Fig. 2). The worse growth performance on saline soil was related to lower absorption of N and P and higher accumulation of Na (sodium) in roots and leaves of all legume species (Fig. 1). As other studies on other plant species, the plant growth retardation on saline soil was related to high accumulation of Na in the plants resulting in lower absorption of other nutrients (18, 26, 27). Growth retardation of some plant species due to salinity was also reported by some investigators (19, 20, 22).

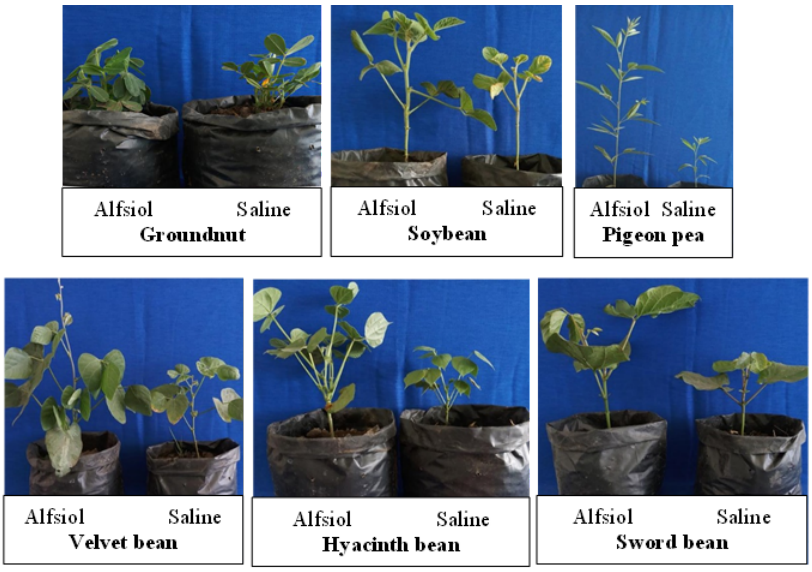

Fig. 2. Effect of salinity on the growth performances of legume crops at 50 DAS (B).

3.3 Plant height of legumes on Alfisol and saline soils

Plant heights of legumes at 15 days after sowing (DAS) and at 50 DAS grown on Alfisol or saline soil varied significantly among the legume species (Figs. 3A and 3C). This result suggests that the variability of plant heigh was determined by the genetic of the legume species. Figures 3A and 3C also depicted that the plant height of each legume species was significantly lower on saline soil than on Alfisol soil. These figures indicate the reducing effect of saline soil (Figs. 2, 3B and 3D). This result is in accordance to the previous findings reporting that the plant height reduction of porang and pigeon pea by salinity (18, 26). The degree of plant height reduction was shown to be different among the legume species (Figs. 3B and 3D). At earlier growth stage (15 DAS), the highest plant height reduction was shown by velvet bean. At later stage, pigeon pea and velvet bean underwent comparably highest plant height reduction caused by saline soil. The least plant height reduction was observed on groundnut at later growing stage. Thus, pigeon pea and velvet bean were classified as the most susceptible legume species to saline environment measured in terms of plant height, whilst, groundnut was termed as the most tolerant legume species to salinity. In general, lower uptake of N and P (Fig. 1), in addition to higher Na of legumes planted on saline soil might result in lower plant height. High Na in saline soil resulted in plant toxicity was depicted in figure 2. Besides, plant height reduction and toxicity of porang by salinity was also revealed by Soedarjo et al. (18).

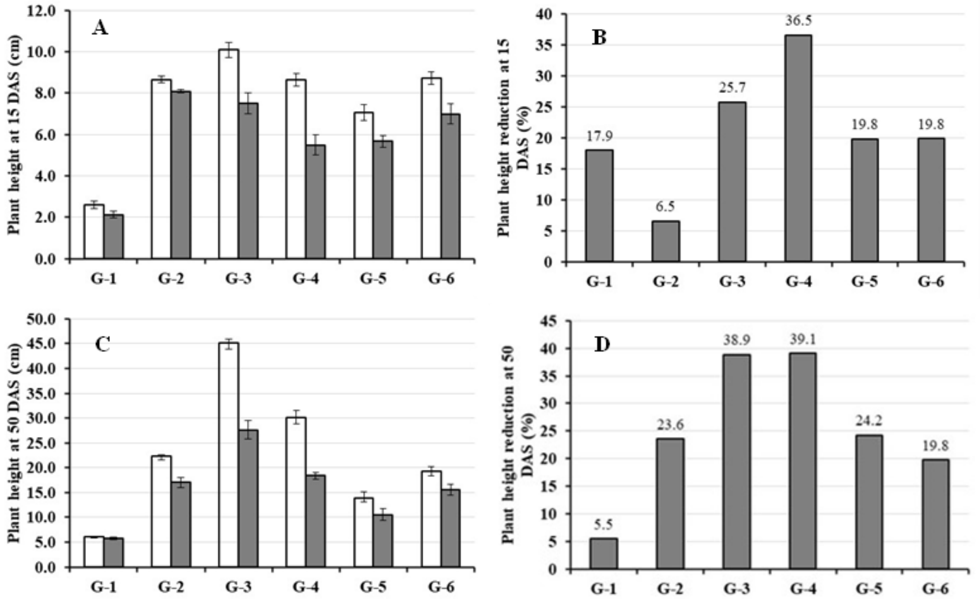

Fig. 3. Effect of salinity on plant height of legume crops at 15 DAS (A), plant height reduction due to salinity at 15 DAS (B), on plant height of legume crops at 50 DAS (C) and plant height reduction due to salinity at 50 DAS (D). Empty and solid bars are Alfisol and saline soils. G-1, G-2, G-3, G-4, G-5 and G-6 on X axis are groundnut, soybean, pingeon pea, velvet bean, hyacinth bean and sword bean.

3.4 Plant diameter of legumes on Alfisol and saline soils

Standard deviation analysis revealed the significant different of plant diameter among legume species grown on either Alfisol soil or saline soil (Fig. 4A). This result leads to the assumption that the variability in plant diameter was related to the different genetic background among the legume species. The plant diameter of each legume species was found to be significantly lower when planted on saline soil than on Alfisol soil, suggesting the harmful effect of salinity on plant diameter. The occurrence of plant diameter reduction could be explained by Na toxicity due to high accumulation of Na in roots and leaves and also by lower N and P absorption (Fig. 1). The previous study also revealed the reduction of plant diameter when the konjac plants were grown on saline soil (18, 26). Pigeon pea, velvet bean and hyacinth bean depicted comparably highest reduction in plant diameter (Fig. 4B) and were considered as the most susceptible legume species to saline environment, consequently.

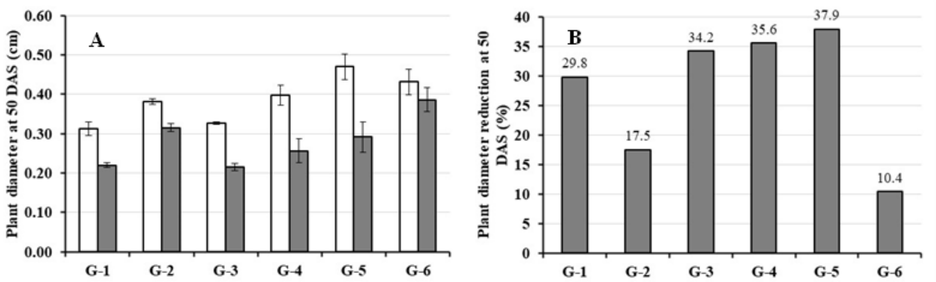

Fig. 4. Effect of salinity on plant diameter of legume crops (A), plant diameter reduction due to salinity at 50 DAS (B). Empty and solid bars are Alfisol and saline soils. G-1, G-2, G-3, G-4, G-5 and G-6 on X axis are groundnut, soybean, pingeon pea, velvet bean, hyacinth bean and sword bean.

3.5 Root dry weight of legumes on Alfisol and saline soils

Significant difference of root dry weight among legume species grown on either Alfisol or saline soils was shown on Figure 5A. Root dry weight of each legume was observed to be significantly lower when planted on saline soil than on Alfisol soil. A significant decline of root dry weight in saline soil as an attribute that saline environment was detrimental to root growth. The intensity of root dry weight reduction due to salinity varied among legume species (Fig. 5B). Lower root growth on saline soil was followed lower growth of plant height (Fig. 3) and lower growth of plant diameter (Fig. 4) and was related to higher Na accumulation in roots and leaves and lower absorption of N and P (Fig. 1). A significant decline of root dry weight on saline soil was also revealed by previous investigators (18, 26) and considered as toxicity symptom due to salinity. A deleterious influence of salinity on root growth maize and on root growth of rice was also reported by Zahra et al (28) and Puvanitha and Mahendran (29). The present study showed that the highest (84%) and lowest (21%) root dry weight decrease due to salinity were depicted by pigeon pea and sword bean, respectively.

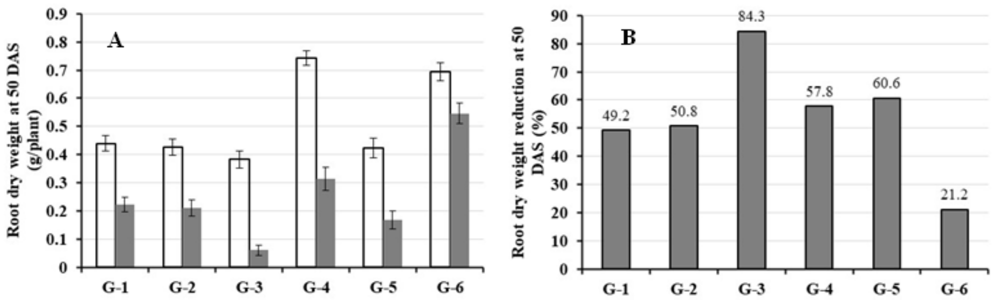

Fig. 5. Effect of salinity on root dry weight of legume crops (A) and root dry weight reduction due to salinity at 50 DAS (B). Empty and solid bars are Alfisol and saline soils. G-1, G-2, G-3, G-4, G-5 and G-6 on X axis are groundnut, soybean, pingeon pea, velvet bean, hyacinth bean and sword bean.

3.6 Shoot dry weight of legumes on Alfisol and saline soils

Like the plant height, plant diameter and root dry weight, the biomass production measured in term of shoot dry weight was also significantly different among legume species grown either on Alfisol or saline soil (Fig. 6A). The difference in genetic background of legume species leads to the difference in plant growth and development which eventually produced different shoot dry weight. However, the root dry weight of each legume species tested was found significantly lower when planted on saline soil than on Alfisol soil. Thus, salinity was also deleterious to the shoot growth. Lower uptake of N and P (Fig. 1) as a result of lower root growth (Fig. 5) of all legume species grown on saline would lower the photosynthesis which eventually resulted in lower shoot growth. A significant decline of shoot growth on some plant species due to salinity was also documented previously (18, 26, 28 and 29). The percentage of deleterious effect of salinity on shoot dry weight among legume species was significantly different (Fig. 6B). Pigeon pea and groundnut showed the most and the least severe shoot growth retardation, respectively.

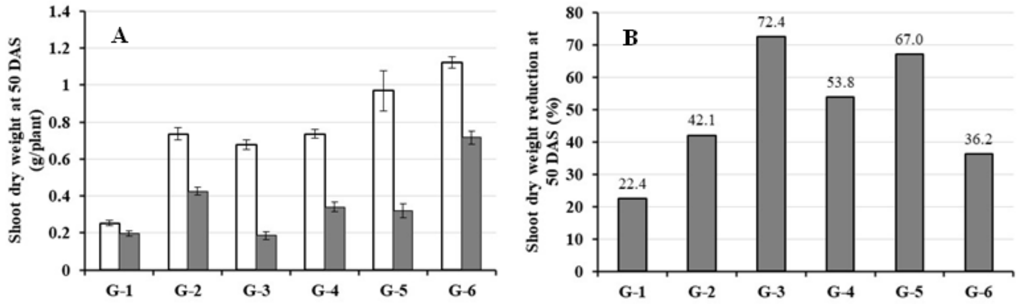

Fig. 6. Effect of salinity on shoot dry weight of legume crops (A) and shoot dry weight reduction due to salinity at 50 DAS (B). Empty and solid bars are Alfisol and saline soils. G-1, G-2, G-3, G-4, G-5 and G-6 on X axis are groundnut, soybean, pingeon pea, velvet bean, hyacinth bean and sword bean.

3.7 Leaf dry weight of legumes on Alfisol and saline soils

Variability of biomass production measured in leaf dry weight within legume species examined was depicted in Figure 7A. Like other growth variables mentioned earlier in this study, the variability in leaf growth was also determined by different genetic background of the legume species tested. Interestingly, all legume species used in the current research produced significantly lower leaf dry weight on saline soil compared to the legume leaf dry weight produced on Alfisol soil (Fig. 7A). The present result indicates a deleterious effect of salinity on leaf growth, like a deleterious effect of salinity on root and shoot growth, plant height and plant diameter. Thus, the growth of all plant parts of legumes was severely reduced by salinity. Zahra et al (28) revealed that a decline of chlorophyl content resulting in significantly lower photosynthetic rate (30) explained the significant reduction in leaf growth as well as in shoot and root growth caused by salinity. On the basis of leaf dry weight, the most and the least severe decline in root dry weight were shown by pigeon pea and ground nut, respectively. Thus, pigeon pea is classified as the most susceptible legume species to salinity whilst groundnut is considered as relatively tolerant legume species to salinity.

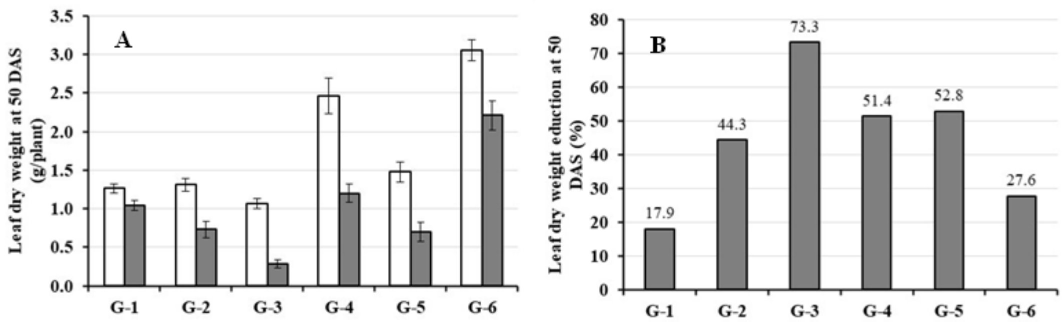

Fig. 7. Effect of salinity on leaf dry weight of legume crops (A) and leaf dry weight reduction due to salinity at 50 DAS (B). Empty and solid bars are Alfisol and saline soils. G-1, G-2, G-3, G-4, G-5 and G-6 on X axis are groundnut, soybean, pingeon pea, velvet bean, hyacinth bean and sword bean.

4 Conclusions

All legume species investigated in the present study showed significantly lower growth, as measured in plant height, plan diameter, root dry weight, shoot dry weight and leaf dry weight, on saline soil than on Alfisol soil. Thus, salinity was found to be detrimental to the growth of the legumes tested. Higher Na accumulation in roots and leaves in saline soil

seems to be deleteriously affect the plant growth. Additionally, lower growth of legumes tested on saline soil was also featured by lower absorption of N and P. Among the legumes tested, pigeon pea showed the most deleteriously affected by salinity and was considered as the most susceptible crop to salinity. Groundnut exhibited the lowest growth retardation on saline soil. Thus, groundnut is classified to be the most potential crop to be cultivated on saline soil.

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