Combating Salinity Stress with Foliar Application of Sodium Antagonistic Essential Minerals on Yield and Yield Attributes of Cotton

Khaing Khaing Aung[1*], Kyi Toe[1], Mie Mie Aung[1], Than Da Min[2], Nyo Mar Htwe[1], Aung Naing Oo[3]

Abstract

The aim in this study was to investigate the appropriate level of foliar application on yield attributes of three tested cotton varieties (Ngwegyi-6, Shwetaung-8 and RAKA-666) for combating salinity stress. The common effect of salinity on plant growth is similar to water stress. Two field experiments were conducted in saline soil at Lungyaw Farm during pre-monsoon seasons, 2015 and 2016. Factorial arrangement in randomized complete block design was used with three replications. Five treatments as non spray (control), water spray, 500 mg L^{-1} KCl, 500 mg L^{-1} NH_4NO_3 and spray mixture (500 mg L^{-1} KCl + 500 mg L^{-1} NH_4NO_3 for 2015 and 250 mg L^{-1} KCl + 250 mg L^{-1} NH_4NO_3 for 2016) were used. Mineral foliar sprays clearly increased number of symbodial branches per plant, bolls per plant and seed cotton yield per plant than non spray treatment, whereas 500 mg L^{-1} NH_4NO_3 was more effective than other sprays in 2015. Number of sympodial branches per plant, bolls per plant, boll weight and seed cotton yield per plant were increased with 250 mg L^{-1} KCl + 250 mg L^{-1} NH_4NO_3 in 2016. Number of monopodial branches per plant was not significant among foliar sprays in both seasons. In 2015, the yield increased was obtained from 500 mg L^{-1} NH_4NO_3 and it was from 250 mg L^{-1} KCl + 250 mg L^{-1} NH_4NO_3 in 2016. However, the highest and satisfactory yield increased was resulted from 250 mg L^{-1} KCl + 250 mg L^{-1} NH_4NO_3. RAKA-666 generally produced highest seed cotton yield in both seasons. Mineral foliar 500 mg L^{-1} NH_4NO_3 in 2015 and the spray mixture in 2016 gave highest harvest index values. Among the tested cotton varieties, there was no difference for HI in 2015 and difference for HI in 2016.

Introduction

Soil salinity is considered as one of the major environmental stresses which adversely affect plant growth and metabolism resulting in considerable losses in crop productivity. In arid and semiarid regions, use of low quality water for irrigation, limited rainfall, high evapotranspiration, high temperature and faulty soil management have further contributed to the salinity problem (Munns and Tester 2008).

The most common effect of salinity on plant growth is similar to water stress. Some plants will tolerate high levels of salinity while others can tolerate little or no salinity. This is because some are better able to make the needed osmotic adjustments enabling them to extract more water from a saline soil. The osmotic effects of salinity are result of increased sodium ion concentrations at the root-soil water interface that creates lower water potential (Ashraf 2004). Although the plants may experience water stress for a short period until they adjust osmotically, water deficit is not the only factor for limited growth, even at relatively high salinities. Growth is reduced as a function of total electrolyte concentration, soil water content and soil matrix effect and is evidenced by reduction in cell division, cell enlargement, cell expansion, cell wall plasticity in the growing region of roots and leaves (Neumann

[1] Department of Plant Breeding, Physiology and Ecology Yezin Agricultural University Yezin, Nay Pyi Taw, Myanmar
[2]Department of Agronomy, Yezin Agricultural University Yezin, Nay Pyi Taw, Myanmar
[3]Department of Soil and Water Science, Yezin Agricultural University Yezin, Nay Pyi Taw, Myanmar

1997).

Ionic toxicity considered responsible for growth inhibitions under excessive saline environment. Salinity reduces plant growth through ionic influences. Salinity affects ion activities in solution by changing the ionic strength, by ion-pair formation, and by precipitation (Cramer et al. 1987). Excessive uptake and transport of the salt ions (Na^+, Cl^- and SO_4^{-2}) and/or an inadequate uptake and transport of essential elements, to produce changes in mineral nutrient uptake that affect plant growth and reduce yields and cause crop failure (Bayuelo-Jiménez et al. 2002). Ion uptake is the cheapest form of osmotic adjustment under soil saline conditions, but it could also lead to problems of decline in leaf function and ionic imbalance and toxicity (Yildirim et al. 2009).

In particular, salinity alters uptake and absorption rates of all mineral nutrients resulting in deficiency symptoms (Bonilla et al. 2004). Excessive accumulation of Na^+ can cause a range of ionic and metabolic problems for plants (Hoai et al. 2003). However, sodium ion toxicity is more prevalent and more toxic to plants. Salinity acts like drought on plants, preventing roots from performing their osmotic activity where water and nutrients move from an area of low concentration into an area of high concentration. Therefore, because of the salt levels in the soil, water and nutrients cannot move into the plant roots. Salt tolerance of a plant is affected under low nutrient availability. Accumulation of Na^+ and Cl^- in leaves through the transpiration flow is a general and long term process taking place in salt-stress plants (Munns and Termaat 1986). Nutrient uptake and accumulation by plants is often reduced under saline conditions as a result of competitive process between the nutrient and a major salt species. However, this depends on the type of nutrients and composition of soil solution (Homaee et al. 2002). Although plants selectively absorb potassium over sodium, Na^+-induced K^+ deficiency can develop on crops under salinity stress by Na^+ salt (Maas and Grattan 1999). In some cases, the uptake and translocation of ions such as K^+ and Ca^{2+} are affected by salt stress.

Being antagonistic to other cations, sodium inhibits entry of plant nutrients in the root system, hence plants suffer deficiency of their mineral elements, which are essential for growth. An immediate response of salinity induced water potential imbalance is closure of stomates, which also effects on the carbon fixation in leaves and causes deficiency of same essential minerals with specific reference to monovalent potassium cation required for enzyme activation and membrane transport. Antagonistic effect of excessive sodium could be avoided in root zone if these essential mono and divalent cations are provided through foliar irrigation to plants (Ahmad and Jabeen 2005).

Foliar application of potassium is an efficient method of potassium supply to plants to avoid interaction both antagonistic and synergistic with essential major secondary and micronutrients (Dibb and Thompson 1985). Therefore, this study was conducted with foliar application of sodium antagonistic minerals for increasing cotton yield under saline condition.

Materials and Methods

Three cotton varieties (Ngwegyi-6, Shwetaung-8 and RAKA-666) were used in this study. Two Experiments were conducted at Cotton Research and Technology Development Farm (Lungyaw), Kyaukse Township, Mandalay Region during pre-monsoon seasons, 2015 and 2016. Five levels of foliar applications as non spray (control), water spray, 500 mg L^{-1} KCl, 500 mg L^{-1} NH_4NO_3 and spray mixture (500 mg L^{-1} KCl + 500 mg L^{-1} NH_4NO_3 for 2015 and 250 mg L^{-1} KCl + 250 mg L^{-1} NH_4NO_3 for 2016) were assigned as factor (A) and three selected cotton varieties were arranged as factor (B). Two factors factorial arrangement in randomized complete block design (RCBD) with three replications to investigate yield and yield attributes of cotton under saline condition. Plot size was 6 m x 6 m including 7 rows and spacing was one meter between row and 0.3 m within plants. The two outer were marked as border rows. Middle three rows were kept for taking plant height and yield data at harvest time. Treatment application was started at 18 DAS and then spraying was continued weekly intervals (total 4 times) up to 39 DAS (before flowering). Before sowing, the soil pH and ECe values were 8.43 and 4.78 dS m^{-1} in 2015 and 8.71 and

6.14 dS m^{-1} in 2016. Farm yard manure at the rate of 5 tons per hectare was applied as basal. Compound fertilizer (15:15:15) at the rate of 125 kg ha^{-1} was used at the sowing time. Urea fertilizer at the rate of 62.5 kg ha^{-1} was applied at the flowering time. Four **c**otton seeds at a spot were sown together with Carbofuran 3G (Armo) at the rate of 7.5 kg ha^{-1} to prevent soil borne diseases. Tow cotton plants were left at the thinning time. Crop management was carried out according to recommended agricultural practices for cotton and pests were controlled if necessary. Number of sympodial branches per plant, number of monopodial branches per plant, number of bolls per plant, seed cotton yield per boll (boll weight), seed cotton yield per plant were recorded. Harvest index was also calculated by using the following formula.

Statistical analysis was performed by using Statistix (version 8.0) program. Mean comparisons were done by Least Significant Difference (LSD) at 5% level.

Results and Discussion

Yield and yield attributed characters of three cotton varieties as affected by mineral foliar sprays (pre-monsoon season, 2015)

Number of sympodial branches per plant

More number of sympodial branches per plant indicates formation of more fruiting points leading to higher yield. Number of sympodial branches per plant under different mineral foliar sprays and different cotton varieties were presented in Table 1. Although sympodial branches per plant were not significantly different among mineral foliar sprays, 500 mg L^{-1} NH_4NO_3 foliar spray produced the highest number of sympodial branches per plant (15.20). The lowest number (14.00) was observed in non spray treatment.

Significant differences in number of sympodial branches per plant among cotton varieties were found in this study. The highest number of sympodial branches per plant (16.60) was observed in RAKA-666 and it was statistically higher than those of Ngwegyi-6 (13.67) and Shwetaung-8 (13.48). The interaction between mineral foliar sprays and cotton varieties was not significantly different. This season investigation proved that mineral foliar sprays were not influenced significantly on number of sympodial branches per plant in tested cotton varieties.

Number of monopodial branches per plant

Number of monopodial branches per plant of three cotton varieties as affected by mineral foliar sprays is presented in Table 1. **N**umber of monopodial branches per plant under different mineral foliar sprays was not significantly different. The lowest number of monopodial branches per plant (1.84) was observed in water spray treatment.

Significant differences in number of monopodial branches per plant among cotton varieties were seen. The lowest number of monopodial branches per plant (1.56) was found in Ngwegyi-6 and it was statistically lower than those of Shwetaung-8 (1.87) and RAKA-666 (2.36). In cotton crop, the lowest number of monopodial branches per plant was desirable character. The interaction between mineral foliar sprays and cotton varieties was not significantly different. Based on these results, the number of monopodial branches per plant was not influenced by mineral foliar sprays in all varieties.

Number of bolls per plant

Number of bolls per plant is the major yield contributing component having strong association with seed cotton yield. Number of bolls per plant of three cotton genotypes as affected by mineral foliar sprays is presented in Table 1. Significant differences among mineral foliar sprays were observed in this study. Highest number of bolls per plant (9.13) was produced by 500 mg L^{-1} NH_4NO_3 and it was statistically higher than boll number from mixture of 500 mg L^{-1} KCl + 500 mg L^{-1} NH_4NO_3 (8.13). Statistically lowest number of bolls per plant (6.22) was observed in non spray treatment. The result was similar to the report of Jabeen and Ahmad (2009) who confirmed that increasing salinity of rooting medium has proportionally decreased the number of bolls per plant and this was offset up to various degree by the spray of different mineral nutrients.

Significant differences were not found among cotton varieties. The interaction between mineral foliar sprays and cotton varieties was not significantly different in this study. It can be said that mineral foliar sprays were highly influenced on number of bolls per plant, whereas different cotton varieties showed inconsistent responses to minerals.

Boll weight

Boll weight of three cotton varieties as affected by mineral foliar sprays is presented in Table 1. In this study, boll weight was not significantly different among foliar sprays. This indicated that mineral foliar sprays showed no effect on this character. According to cotton varieties, their boll weights were significantly different. The largest boll (4.38 g) was produced by Shwetaung-8 and the smallest boll (4.11 g) was observed in Ngwegyi-6. This indicated that different cotton varieties produced different weight of boll. The interaction between mineral foliar sprays and cotton varieties were not significantly different. Based on these

Table 1. Yield and yield attributed characters of three cotton varieties as affected by mineral foliar sprays

Treatment	SP (no.)	MP (no.)	BP (no.)	BW (g)	SCYP (g)	HI
Mineral foliar sprays (A)						
Non spray	14.00	1.96	6.22	4.38	27.56	0.44
Water spray	14.58	1.84	6.92	4.24	29.91	0.44
500 mg L^{-1} KCl	14.58	1.96	6.90	4.16	28.93	0.42
500 mg L^{-1} NH_4NO_3	15.20	1.96	9.13	4.36	39.91	0.53
500 mg L^{-1} KCl + 500 mg L^{-1} NH_4NO_3	14.56	1.93	8.13	4.16	33.87	0.46
LSD $_{0.05}$	1.88	0.23	0.71	0.26	3.99	0.04
Cotton varieties (B)						
Ngwegyi-6	13.67	1.56	7.23	4.11	29.99	0.45
Shwetaung-8	13.48	1.87	7.55	4.38	33.20	0.47
RAKA-666	16.60	2.36	7.60	4.29	32.91	0.46
LSD $_{0.05}$	1.46	0.18	0.55	0.20	3.09	0.03
P≥F						
Mineral foliar sprays	0.788	0.825	≤ 0.000	0.264	≤ 0.000	≤ 0.0000
Cotton varieties	≤ 0.000	≤ 0.000	0.348	0.031	0.081	0.6462
(A) X (B)	0.593	0.959	0.232	0.325	0.209	0.0003
CV %	13.37	12.24	9.89	6.35	12.91	8.08

SP = Number of sympodial branches per plant, MP = Number of monopodial branches per plant, BP = Number of bolls per plant, BW = Boll weight, SCYP = Seed cotton yieldper plant, HI = Harvest index

findings, different cotton varieties contributed to different boll weight under the application of mineral foliar sprays.

Seed cotton yield per plant

Seed cotton yield per plant was greatly associated with yield components as number of bolls per plant, boll weight and it could be increased by increasing these related components. Seed cotton yield per plant of three cotton varieties as affected by mineral foliar sprays is presented in Table 1. Significant differences in seed cotton yield per plant among mineral foliar sprays were observed in this study. The highest seed cotton yield per plant (39.91 g) was produced by 500 mg L^{-1} NH_4NO_3 and the lowest (27.56) was observed in non spray treatment.

Table 2. Yield and yield attributed characters of three cotton varieties as affected by mineral foliar sprays

Treatment	SP (no.)	MP (no.)	BP (no.)	BW (g)	SCYP (g)	HI
Mineral foliar sprays (A)						
Non spray	19.24	1.95	7.72	4.87	37.52	0.46
Water spray	19.76	1.84	8.30	4.79	39.61	0.45
500 mg L^{-1} KCl	20.02	1.95	9.57	5.09	48.85	0.47
500 mg L^{-1} NH_4NO_3	19.73	1.95	10.59	5.01	52.92	0.50
250 mg L^{-1} KCl + 250 mg L^{-1} NH_4NO_3	20.42	1.93	12.39	5.41	67.02	0.52
$LSD_{0.05}$	0.58	0.22	0.98	0.32	5.42	0.03
Cotton varieties (B)						
Ngwegyi-6	19.97	1.56	9.36	5.07	48.02	0.47
Shwetaung-8	19.40	1.87	8.90	5.12	45.81	0.46
RAKA-666	20.13	2.36	10.89	4.91	53.72	0.50
$LSD_{0.05}$	0.45	0.17	0.76	0.24	4.19	0.02
P≥F						
Mineral foliar sprays	0.006	0.800	$\leq$0.000	0.004	$\leq$0.000	0.0003
Cotton varieties	0.006	$\leq$0.000	$\leq$0.000	0.192	0.002	0.0099
(A) X (B)	0.215	0.947	0.776	0.924	0.601	0.7276
CV %	3.04	11.71	10.49	6.53	11.41	6.72

SP = Number of sympodial branches per plant, MP = Number of monopodial branches per plant, BP = Number of bolls per plant, BW = Boll weight, SCYP = Seed cotton yield per plant, HI = Harvest index

The result was similar to the report of Jabeen and Ahmad (2009) who stated that the adverse effects of salinity on seed cotton yield could be overcome by spraying different mineral nutrients.

Seed cotton yield per plant was not significantly different among cotton varieties. However, the highest seed cotton yield per plant (33.20 g) was received from Shwetaung-8 which was not significantly different from RAKA-666 (32.91 g) and the lowest (29.99 g) was produced by Ngwegyi-6. There was no interaction between mineral foliar sprays and cotton varieties. According to these results, mineral foliar spray was strongly influenced on increasing seed cotton yield per plant in tested cotton varieties under saline condition.

Harvest index (HI)

Harvest indices of tested cotton varieties as affected by different mineral foliar sprays are presented in Table 1. Harvest indices were significantly different among mineral foliar sprays in this study. The highest HI (0.53) was observed by applying with 500 mg L^{-1} NH_4NO_3 and the lowest value (0.42) from 500 mg L^{-1} KCl. In this investigation, 500 mg L^{-1} NH_4NO_3 produced statistically highest harvest index.

Among the cotton varieties, HI was not significantly different. Significant differences of HI were found in interaction between mineral foliar sprays and cotton varieties. According to these results, mineral foliar sprays showed the highest effect on harvest index of related cotton varieties.

Yield and yield attributed characters of three cotton varieties as affected by mineral foliar sprays (pre-monsoon season, 2016)

Number of sympodial branches per plant

Number of sympodial branches per plant of three cotton varieties as affected by mineral foliar sprays is presented in Table 2. Number of sympodial branches per plant was significantly different among mineral foliar sprays. The highest number of sympodial branches per plant (20.42) was observed in applying 250 mg L^{-1} KCl + 250 mg L^{-1} NH_4NO_3 spray mixture and it was not statistically different from 500 mg L^{-1} KCl (20.02). The lowest outcome (19.24) was found in non spray treatment. Exogenous application through foliar spray of essential elements like K was found promising to enhance the growth of the crop plant. Azeem and Ahmad (2011) confirmed that increase in number of tomato fruiting branches were less under spray of individual mineral element in comparison with their mixture but still more than non spray control.

Significant differences among three tested cotton varieties were recorded in this season also. RAKA-666 produced the highest number of sympodial branches per plant (20.13) while Shwetaung-8 showed the lowest number (19.40). Variety response to foliar spray was the same as first season.

There was no interaction between mineral foliar sprays and cotton varieties. Based on these results, the formation of highest number of sympodial branches per plant among tested cotton varieties was influenced by mineral foliar sprays especially with K nutrient application.

Number of monopodial branches per plant

Number of monopodial branches per plant of three cotton varieties as affected by mineral foliar sprays is presented in Table 2. Number of monopodial branches per plant under different mineral foliar sprays was not significantly different. Water spray produced the lowest monopodial branches per plant (1.84).

Significant differences among cotton varieties were observed. RAKA-666 showed the highest number of monopodial branches per plant (2.36) while Ngwegyi-6 expressed the lowest (1.56). The interaction between mineral foliar sprays and tested cotton varieties was not significantly different. According to these results, the number of monopodial branches per plant was not influenced by mineral foliar sprays in all varieties and the lowest number was desirable character in general.

Number of bolls per plant

Number of bolls per plant of three cotton varieties as affected by mineral foliar sprays is presented in Table 2. Number of bolls per plant was significantly different among mineral foliar sprays and also among cotton varieties. The highest number of bolls per plant (12.39) was observed in 250 mg L^{-1} KCl + 250 mg L^{-1} NH_4NO_3 spray mixture and the lowest (7.72) was produced from non spray treatment.

The maximum number of bolls per plant (10.89) was picked from RAKA-666 and the lowest (8.90) was produced from Shwetaung-8. There was no interaction between mineral foliar sprays and cotton varieties. Based on these results, number of bolls per plant was highly influenced by 250 mg L^{-1} KCl and 250 mg L^{-1} NH_4NO_3 spray mixture for all cotton varieties.

Boll weight

Boll weight of three cotton varieties as affected by mineral foliar sprays is presented in Table 2. Boll weights under the application of different mineral foliar sprays were significantly different. The highest weight of boll (5.41 g) was observed in 250 mg L^{-1} KCl + 250 mg L^{-1} NH_4NO_3 spray mixture and the lowest (4.79 g) from water spray treatment.

There were not significant differences in boll weight among cotton varieties. Moreover, the interaction between mineral foliar sprays and cotton varieties were not significantly different. It can be noted that mineral foliar sprays influenced differently on boll weight of different cotton varieties.

Seed cotton yield per plant

Seed cotton yield per plant of three cotton varieties as affected by mineral foliar sprays is presented in Table 2. Seed cotton yield per plant among mineral foliar sprays was significantly different. The significantly highest seed cotton yield (67.02 g) was observed in 250 mg L^{-1} KCl + 250 mg L^{-1} NH_4NO_3 and the lowest (37.52 g) from non spray treatment. This increase in seed cotton yield was due to the application of potassium together with nitrogen nutrient application (Dewdar and Rady 2013). Brar and Tiwari (2004) reported increase in yield of cotton by 22% by foliar application of KCl. Jabeen and Ahmad (2009) stated that foliar spray of NH_4NO_3 and KCl in combination increase seed cotton yield by 92.00% and 98.00% under sea salt dilutions of 6.2 and 10.8 dS m^{-1} irrigation water respectively.

There were significant differences in seed cotton yield among cotton varieties. The highest seed cotton yield per plant (53.72 g) was observed in RAKA-666 and the lowest yield (45.81 g) from Shwetaung-8. The interaction between mineral foliar sprays and cotton varieties was not significantly different. According to these findings, mineral mixture showed the highest effect on all tested cotton varieties.

Harvest index (HI)

Harvest indices of tested cotton varieties as affected by different mineral foliar sprays are presented in Table 2. Harvest index was significantly different among mineral foliar sprays. The highest HI (0.52) was found in the application of 250 mg L^{-1} KCl + 250 mg L^{-1} NH_4NO_3 and the lowest (0.45) from water spray treatment. In this study, spray mixture produced statistically highest harvest index.

Cotton varieties were also significantly different in HI. The highest HI (0.50) was observed in RAKA-666 and the lowest value (0.46) was found in Shwetaung-8. There was no relation between mineral foliar sprays and cotton varieties. Based on these results, the application of spray mixture was more effective for increasing economic yields of all tested cotton varieties.

Conclusion

Cotton plant is classified as salt tolerant crop. Under saline environment, the deleterious effect of excessive sodium was significantly inhibited due to the foliar application of 500 mg L^{-1} NH_4NO_3 in 2015 and mixture of 250 mg L^{-1} KCl + 250 mg L^{-1} NH_4NO_3 in 2016 and if brought into practice could increase productivity of cotton. Mineral foliar sprays clearly increased number of symbodial branches per plant, bolls per plant and seed cotton yield per plant than non spray treatment, whereas 500 mg L^{-1} NH_4NO_3 was more effective than other sprays in 2015. In 2016, number of sympodial branches per plant, bolls per plant, boll weight and seed cotton yield per plant were increased with the application of mixture of 250 mg L^{-1} KCl + 250 mg L^{-1} NH_4NO_3. Number of monopodial branches per plant was not significant among foliar sprays in both seasons. In 2015, the yield increased was obtained from the application of 500 NH_4NO_3. However, in 2016 investigation, the yield response was resulted from the treatment with 250 mg L^{-1} KCl + 250 mg L^{-1} NH_4NO_3. Among the tested cotton varieties, RAKA 666 generally produced highest seed cotton yield in both seasons. Although HI was evidently increased by 500 mg L^{-1} NH_4NO_3 mineral foliar application in 2015, the spray mixture gave the highest index value in 2016. Among the tested cotton varieties, there was no difference for HI in 2015 and difference for HI in 2016.

Acknowledgements

The financial support provided through Forest Resource Environment Development and Conservation Association (FREDA) in Myanmar and by Nagao Natural Environment Foundation (NEF) Japan for conducting this study is highly acknowledged. I also wish to express my sincere thankfulness to U Han Nyunt, Professor (retired), YAU for checking English skill in paper published in Journal of Agricultural Research.

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