ISSN 1810-3030 (Print) 2408-8684 (Online)

Journal of Bangladesh Agricultural University

Journal home page: http://baures.bau.edu.bd/jbau

Increasing yield of maize through potash fertilizer management in saline soil

Mohammad Asadul Haque✉

Department of Soil Science, Patuakhali Science and Technology University, Dumki, Patuakhali 8602, Bangladesh

ARTICLE INFO

Article history:
Received: 02 December 2019
Accepted: 26 March 2020
Published: 30 June 2020

Keywords:
Maize,
Na-K ratio,
Potash,
Soil salinity

Correspondence:
Mohammad Asadul Haque
✉: masadulh@yahoo.com

OPEN ACCESS

ABSTRACT

Soil salinity is a serious abiotic stress which restricts the crop growth in saline soil. In spite of having huge effort globally, still there is a limited success in developing technology for sustainable saline soil management. The present experiment aimed at reducing the detrimental effect of salt on crops by judicious use of K fertilizer in saline soils. The experiment was carried out during rabi season of 2017 in farmers' field of Tajepara village of Kalapara upazila under Patuakhali district, Bangladesh. It was laid out in a randomized complete block design with three replications, each plot size being 5 × 3 m. There were nine treatments, namely control or K omission (T1), next four treatments consisting of 100% recommended K fertilizer dose (RKFD) (T2), 125% RKFD (T3), 150% RKFD (T4) and 175% RKFD (T5) which were applied as basal; another four treatments having 100% RKFD (T6), 125% RKFD (T7), 150% RKFD (T8) and 175% RKFD (T9) applied in two equal splits- one half as basal and one half at 55 days after sowing. The test crop was maize and the variety was ACI Hybrid maize (Don 111). The results revealed that salinity mostly affected reproductive growth, not vegetative growth. Application of K fertilizer significantly reduced the deleterious effect of soil salinity. The K fertilizer recommendation (100% RKFD) as outlined in FRG-2012 was found insufficient, a 25 % higher rate was found as the best for achieving higher yield of maize in saline soil. Split application (half basal+half at 55 DAS) of K was found better than single basal application. The 125% rate of K application is therefore recommended for growing maize in coastal saline soils of Bangladesh.

Copyright ©2020 by authors and BAURES. This work is licensed under the Creative Commons Attribution International License (CC By 4.0).

Introduction

Severe soil and water salinity seriously restricts the expansion of rabi crop growing areas in the southern coastal areas of Bangladesh. On the otherhand, both magnitude and extent of soil salinity in the coastal region are increasing with time, being 0.83 mha in 1973, 1.02 mha in 2002 and 1.06 mha in 2009 (SRDI, 2010). These changes negatively affect on soil fertility and crop productivity which underpins the rural economy and livelihood of coastal Bangladesh. The prevailing situation calls an urgent need to develop an appropriate technology to compensate the crop loss which occurs due to salinity. Thus, introduction of new crops in the rabi season and increasing cropping intensity is challenging in the coastal region of Bangladesh.

Growing maize in the rabi season is seriously hampered by soil and water salinity. Substantial reduction in leaf and root elongation rate is observed after onset of salt stress (Yeo *et al*., 1991). Another major constraint is the specific sodium ion (Na^+) toxicity. Because of the similarity in physicochemical properties between Na^+ and K^+ (i.e. ionic radius and ion hydration energy), the former competes with K^+ for major binding sites in key metabolic processes in the cytoplasm, such as enzymatic reactions, protein synthesis and ribosome functions (Marschner, 1995). Another major constraint is salinity-induced nutritional disorders specifically, K^+ deficiency. First, high concentrations of Na^+ in the soil substantially reduce the activity of K^+, making them less available for plants. Secondly, Na^+ competes with K^+ for uptake sites at the plasma membrane (Shabala and Cuin, 2007; Haque *et al*., 2014; Haque *et al*., 2018).

A liberal application of K may increase the K content in soil and concomitant increase of K uptake which will make the plant tolerant to salt stress. The present experiment was undertaken to increase crop production through reduction of salt effect by application of K fertilizer and to develop K fertilizer management technologies for saline soils in southern coastal region of Bangladesh.

Materials and Methods

The experiment was carried out during rabi season of 2017 in farmers' field at Tajepara village of Kalapara upazila under Patuakhali district, Bangladesh. Experimental field was a medium high land under the AEZ 13 (Ganges Tidal Floodplain). Texturally the soil was loam having 26.9 % sand, 52.5 % silt and 20.6 % clay. The initial soil that collected in January 2017 contained 5.6 pH, 1.14 % organic matter, 0.09 % total N, 8.5 mg kg^{-1} available P and 36.2 mg kg^{-1} available S, and

Cite this article

Haque, M.A. 2020. Increasing yield of maize through potash fertilizer management in saline soil. *Journal of Bangladesh Agricultural University*, 18(2): 362–366. https://doi.org/10.5455/JBAU.76119

30.5 and 25.8 mg kg^{-1} exchangeable K and Na, respectively. The experiment was laid out in a randomized complete block design with three replications, each plot size being 5 × 3 m. There were nine treatments: K control or K omission (T1), the next four treatments consisting of 100% recommended K fertilizer dose (RKFD) (T2), 125% RKFD (T3), 150% RKFD (T4) and 175% RKFD (T5) which was applied only as basal; another four treatments having 100% RKFD (T6), 125% RKFD (T7), 150% RKFD (T8) and 175% RKFD (T9) were applied in two equal splits- one half as basal and one half at 55 days after sowing.

The test crop was maize and the variety was ACI Hybrid maize (Don 111). A blanket dose of N, P, S, Zn and B fertilizer were applied @ 200, 50, 45, 4 and 2 kg ha^{-1}, respectively for proper nutrition of the crop. The fertilizers used were urea (46% N), TSP (20% P), KCl (50% K), gypsum (18% S), zinc sulfate (23% Zn) and boric acid (17% B). In the experiment the 100 kg K/ha rate was regarded as 100% recommended K fertilizer dose (FRG, 2012). Basal application of P, S, Zn and B were made during final land preparation. Nitrogen was top dressed at 3 equal splits – during final land preparation and 30 and 55 days after sowing. Potassium fertilizer was applied according to the treatments and layout. The maize seeds were sown on 14 January 2017 maintaining a spacing of 60×25 cm. Seeds were sown following dibbling methods in line. Two weeding cum earthing-up followed by irrigation was made after urea fertilizer application. All crop protection measures were taken to prevent insect and disease attacks. The yield and yield contributing data were recorded on 4 m^2 area of harvest in each plot. Observation was made in terms of growth, yield and yield components.

Data recorded on crop characters were subjected to statistical analysis through computer based statistical program STAR (Statistical Tool for Agricultural Research, 2013) following the basic principles, as outlined by Gomez and Gomez (1984).

Grain and straw samples were chemically analyzed for determination of K and Na content. The oven dry (65°C) plant samples were digested in nitric-perchloric acid solution (3:1) at 185°C. The K and Na concentrations in the acid digest were determined directly by flame photometer (Yoshida *et al*., 1976).

Results and Discussion

Growth and yield components of maize

Application of K fertilizer (MoP) had significant effect on plant height and the number of leaves per plant (Table 1). However, rate and split application of K had no significant effect on these growth parameters. It has appeared from the findings that a smaller rate of K was required for better growth of maize, but higher rate had discouraging effects (Table 1).

Table 1. Growth and yield components of maize as influenced by potassium application

Treatments	Plant height (cm)	Leaves/plant	Cob length (cm)	Fertile seeds/row	% Sterility
T1: Control	168.0 b	10.6 b	8.2 e	7.5 e	53.9 a
T2: 100% RKFD (Basal)	203.2 a	12.1 ab	9.1 bc	11.2 de	42.7 b
T3: 125% RKFD (Basal)	207.3 a	12.4 a	13.0 a	18.2 ab	21.3 ef
T4: 150% RKFD (Basal)	212.5 a	12.4 a	12.3 ab	13.7 cd	36.5 bcd
T5: 175% RKFD (Basal)	201.1 ab	11.9 ab	10.9 abc	13.9 cd	38.6 bc
T6: 100% RKFD (2 split)	211.7 a	12.4 a	13.3 a	15.1 bc	29.0 de
T7: 125% RKFD (2 split)	220.7 a	12.3 a	13.8 a	21.6 a	15.2 f
T8: 150% RKFD (2 split)	212.0 a	12.6 a	13.2 a	19.6 a	21.1 ef
T9: 175% RKFD (2 split)	203.0 a	11.5 ab	11.7 abc	14.7 bcd	33.5 cd
CV (%)	5.80	4.35	10.97	8.95	8.81
Significance level	**	**	***	***	***

Similar letters in a column are not significantly different at 5% level by DMRT; **, $P<0.01$; ***, $P<0.001$
RKFD= Recommended potassium fertilizer dose, CV= Coefficient of variation

Cob length was significantly influenced by K application. The lowest cob length (8.2 cm) was found in control treatment and the highest result was due to 125% RKFD applied in two equal splits, which was not statistically different from the other K treatments. Among the growth and yield contributing characters, the number of fertile seeds per row was very significantly influenced by K application in saline soil. Only 7.5 numbers of fertile seed was found in a seed row of maize cob in control plot. Potassium application had tremendous positive effect on grain fertility of maize and among the treatments the highest number (21.6) of seeds/cob-row was found in 125% RKFD applied in two splits. The 100, 125, 150 and 175 % RKFD as sole basal application resulted in 49, 143, 83 and 85 % increased number of fertile seeds/cob-row over control treatments, and regarding split application these K fertilizer doses had 101, 188, 161 and 96 % increase, respectively. The number of fertile seeds produced in K applied treatments had a positive reflection on the grain yield of maize. Similar to fertile seeds, the percent sterility of maize was highly influenced by K treatments. An amount of 53.9% sterility was found in control treatment while the lowest sterility (15.2%) was in 125% RKFD applied in two equal splits treatment. Zelelew *et al*. experimented on potato (*Solanum tuberosum* L.) growth with five K doses (0, 75, 150, 225, and 300 kg K_2O ha^{-1}) and found that the plant height, aerial stem number, and leaf number per plant increased with the increasing K levels from 0 kg to 150 kg ha^{-1}.

Grain and straw yields

The grain yield was significantly influenced by the K treatments (Table 2). The lowest grain yield was obviously found in control treatment where no K was applied. Application of 100, 125, 150 and 175 % RKFD as basal had 134, 201, 126 and 115 % higher grain yield and split application at the same rate had 130, 252, 181 and 118 % higher yield over control, respectively. For both sole basal and split treatments the 125 % RKFD treatment showed the highest yield over control treatment indicating that the present K fertilizer recommendation (100% RKFD) needs revision for updating K fertilizer dose in order to obtain higher yield of maize in saline soil. The 25 % increase from present recommendation is better for maize seed production; application of higher K dose (150 and 175 % RKFD) had no positive impact on grain yield. Unlike grain yield, straw yield was not significantly influenced by K application. The lowest (7.39 t/ha) straw yield was observed in K omission (control) treatment. In K applied treatments the range of straw yield was 9.02 to 10.58 t/ha (Table 2).

Table 2. Grain and straw yields of maize as influenced by potassium application

Treatments	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (HI)
T1: Control	2.36 d	7.378	24.2 c
T2: 100% RKFD (Basal)	3.16 d	9.21	25.5 c
T3: 125% RKFD (Basal)	7.11 ab	9.60	42.6 ab
T4: 150% RKFD (Basal)	5.34 bc	10.58	33.5 bc
T5: 175% RKFD (Basal)	5.08 c	9.61	34.7 bc
T6: 100% RKFD (2 split)	5.45 bc	9.30	37.0 ab
T7: 125% RKFD (2 split)	8.32 a	9.56	46.6 a
T8: 150% RKFD (2 split)	6.65 abc	9.06	42.5 ab
T9: 175% RKFD (2 split)	5.16 c	9.02	36.3 ab
% CV	12.02	11.8	10.14
Significance level	***	NS	***

Similar letters in a column are not significantly different at 5% level by DMRT; ***, $P<0.001$; NS = Not significant; RKFD= Recommended potassium fertilizer dose, CV= Coefficient of variation

The harvest index, calculated as HI = Grain yield / (grain yield + straw yield) × 100 was significantly influenced by different levels of K application, the range from 24.2 to 46.6 %; lowest being in control and highest in 125% RKFD (T7) with split application (Table 2). The highest harvest index obtained in T7 treatment was statistically similar to T3 (125% RKFD applied as basal), T8 (150% RKFD with two split application), T6 (100% RKFD with split application) and T9 (175% RKFD with split application) treatments. The results evidenced that 100% RKFD is not sufficient for maize cultivation in saline soil. The 125% RKFD is the best treatment. The excessively higher rate like 150 and 175 % RKFD is considered as wasteful.

For comparison between sole and split application of K fertilizer, the mean of T2, T3, T4 and T5 was calculated to represent the contribution of basal applied K, and similarly mean value of T6, T7, T8 and T9 shows the contribution of split application of K. It was found that grain yield and harvest index increased by 23.6% and 19.1%, respectively in split applied treatment over basal application. Heidari and Jamshid (2010) reported that by increasing salinity from 0 to 12 dS/m grain yield (45.6%), biological yield (35.3%), harvest index (15.1%) and 1000 seed weight (60.1%) decreased; however, by application from 0 to 200 kg ha^{-1} potassium, grain yield (11.7%), biological yield (24.2%) and 1000 seed weight (41.1%) increased.

Grain and straw K and Na concentration

The K concentration in maize grain ranged from 0.46% to 0.77% over the treatments (Fig. 1), the K concentration was the lowest in control. The K concentration progressively increased with the increase of K application. The basal application of 100, 125, 150 and 175 % RKFD produced 0.53, 0.53, 0.53 and 0.61 % K in grain; whereas in split application of K at similar rate had 0.56, 0.55, 0.54 and 0.77 % K in maize grain, respectively. The straw K concentration was found several folds higher than the grain K concentration. The straw K concentration over the treatments varied from 0.93% (control treatment) to 1.55% (150% RKFD in 2 split) (Fig. 1). In the experiment 21, 30, 43 and 42 % increase in %straw K content was found in 100, 125, 150 and 175 % RKFD as basal, which was 41, 59, 68 and 56 % in the respective split applied treatments, respectively. As reported by Bar-Tal *et al. (*2004), the K fertilization had beneficial effect on increasing K concentration in saline soil and reducing the Na:K ratio in corn plant tissue. The K concentration of leaves under salinity treatments, significantly increased and Na concentration decreased with increasing K levels from 0 to 200kg ha^{-1} (Badr and Shafei, 2002). Addition of K^+ increased K^+ concentrations and suppressed sodium (Na^+) concentration, which eventually increased the K^+/Na^+ ratios in roots or shoots (Li and Si, 2019).

The grain Na content ranged from 0.03 to 0.06 % over the treatments (Fig. 2). In control treatment, the grain Na concentration was the highest. In 100 to 175% RKFD treatments, the grain Na content varied from 0.03 to 0.06 % in sole basal application treatments, and from 0.03 to 0.04 % in split application of K treatments. The Na concentration of grain was found comparatively lower than its K concentration. Probably there have some mechanisms by which plant make a barrier so that excess Na cannot enter into the grain. Generally, the Na concentration of grain decreased with increase of K concentration in both grain and straw. Over control treatment in grain the Na concentration decreased by 3, 10, 10 and 55 % in basal, and 32, 55, 55 and 42 % in split application of 100, 125, 150 and 175 % RKFD treatments, respectively.

Regarding straw, the highest Na concentration was also recorded in control treatment. The straw Na concentration in basal application of 100, 125, 150 and 175% RKFD treatments had 1.623, 1.426, 1.518 and 0.676 % Na and that of 1.50, 1.49, 1.08 and 0.95 % in split application, respectively (Fig. 2).

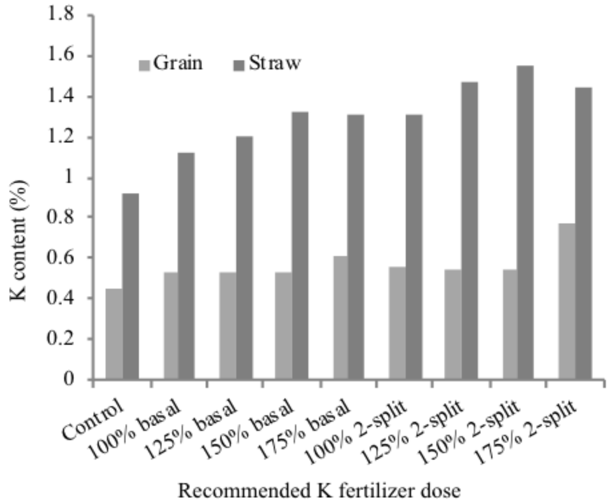

Fig. 1. Potassium content of maize under different K fertilizer treatment

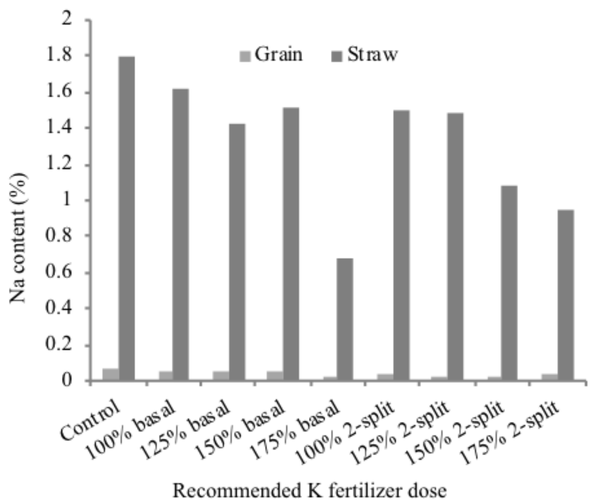

Fig. 2. Sodium content of maize under different K fertilizer treatment

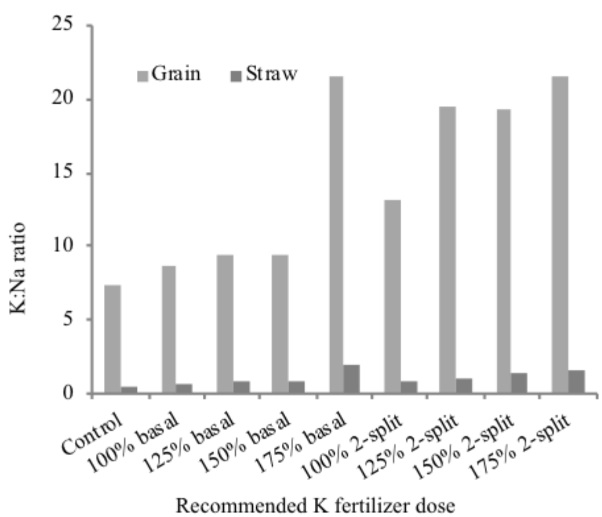

Fig. 3. Potassium: Sodium ratio of maize under different K fertilizer treatment

The Na uptake by the roots is mainly accumulated in the vegetative part of the crop, so comparatively higher level of Na was found in maize straw. Similar to grain the straw Na content gradually decreased with the increase in the rate of K application in soil. The findings are in agreement with the findings of Kaya *et al.* (2013) who reported that leaf sodium (Na^+) concentration increased substantially in maize plants exposed to saline stress, but exogenous application of K considerably reduced Na^+ concentration in the leaves of maize plants grown under saline stress.

The decrease in Na^+ content can be attributed to K^+ competition with Na^+ for binding sites on the plasma membrane which suppressed the influx of Na^+ from the external solution (Al-Uqaili, 2003). The K:Na ratio was found much higher in grain than in straw. The grain K:Na ratio progressively increased with the rates of K application. Regarding sole basal application the 100% RKFD gave K:Na ratio of 8.70 which increased to 21.5 due to 175% RKFD treatment (Fig. 3). In split application treatments the grain K:Na ratio in 100% RKFD was 1.20 and it increased to 21.57 in 175% RKFD treatment. The straw K:Na ratio varied from 0.51 in control treatment to 1.94 in 175% basal application of RKFD (Fig. 3). The K:Na ratio in basal application of 100, 125, 150 and 175 % of the RKFD was 0.69, 0.85, 0.87 and 1.94, which was 0.87, 0.99, 1.43 and 1.52 in split application treatments, respectively.

The K:Na ratio in both grain and straw increased with the increasing rate of K application. The higher amount of applied K successfully competes with Na for absorption site. The higher rate of K application reduced the accumulation of Na in plant. The increasing rate of applied K therefore increased the K concentration in plant and concomitantly reduced the Na concentration which ultimately resulted in higher K:Na ratio. Many studies showed that addition of K mitigated the undesirable effects of Na and improved K uptake of cucumber and pepper (Kaya *et al.*, 2001), and improved K:Na ratio under salt stress (Abbasi *et al.*, 2014).

Conclusion

Potassium fertilizer makes plants tolerant to salt stress. The recommendation (100% RKFD) as stated in FRG-2012 could be sufficient for vegetative growth, however 25% extra K application would help achieving higher grain yield of maize in saline soil. The two split application of K showed better performances than sole basal application.

Acknowledgement

This work was supported by the Bangladesh University Grants Commission (UGC) under the project entitled "Reduction of salt induced crop loss through management of potassium fertilizer in southern coastal region of Bangladesh".

References

Abbasi, G.H., Akhtar, J., Haq, M.A., Ali, S., Chen, Z. and Malik, W., 2014. Exogenous potassium differentially mitigates salt stress in tolerant and sensitive maize hybrids. *Pakistan Journal of Botany*, 46(1): 135-146.

Al-Uqaili, J.K., 2003. Potential of using drainage water for wheat production in Iraq. *Emirates Journal of Agricultural Science*, 15: 36-43. https://doi.org/10.9755/ejfa.v15i1.5280

Badr, M.A. and Shafei, A.M., 2002. Salt tolerance in two wheat varieties and its relation to potassium nutrition. *Al-Azhar Journal of Agricultural Research*, 35: 115-128.

Bar-Tal, A.S. and Sparks, D.L.F., 2004. Potassium-salinity interaction in irrigated corn. *Irrigation Science,* 12: 27-35. https://doi.org/10.1007/BF00190706

FRG 2012. Fertilizer Recommendation Guide. Bangladesh Agricultural Research Council. Farmgate, Dhaka.

Gomez, K.A. and Gomez, A.A., 1984. Statistical Procedures for Agricultural Research, John Wiley and Sons, New York.

Haque, M.A., Jahiruddin, M., Hoque, M.A., Rahman, M.Z. and Clarke, D., 2014. Temporal variability of soil and water salinity and its effect on crop at Kalapara Upazila. *Journal of Environmental Science & Natural Resources*, 7(2): 111-114. https://doi.org/10.3329/jesnr.v7i2.22218

Haque, M.A., Jahiruddin, M and Clarke, D. 2018. Effect of plastic mulch on crop yield and land degradation in south coastal saline soils of Bangladesh. International Soil and Water Conservation Research, 6(4): 317-324.

Heidari, M. and Jamshid, P., 2010. Interaction between salinity and potassium on grain yield, carbohydrate content and nutrient uptake in pearl millet. ARPN *Journal of Agricultural and Biological Science*, 5(6): 39-46.

Kaya, C., Ashraf, M., Dikilitas, M. and Tuna, A.L., 2013. Alleviation of salt stress-induced adverse effects on maize plants by exogenous application of indoleacetic acid (IAA) and inorganic nutrients – A field trial. *Australian Journal of Crop Science*, 7(2):249-254. https://doi.org/10.1081/PLN-100001394

Kaya, C., Kirnak, H. and Higgs, D., 2001. Enhancement of growth and normal growth parameters by foliar application of potassium and phosphorus in tomato cultivars grown at high (NaCl) salinity. *Journal of Plant Nutrition,* 24: 357-367.

Li, H.Y. and Si, D.X., 2019. Effect of potassium on uptake and translocation of sodium and potassium in Chinese cabbage under NaCl stress. *Journal of Plant Nutrition*, 43(3): 250-260. https://doi.org/10.1080/01904167.2018.1554078

Marschner, H., 1995. The Mineral Nutrition of Higher Plants. Academic Press, London

Shabala, S. and Cuin, T.A., 2007. Potassium transport and plant salt tolerance. *Physiologia Plantarum*, 133: 651–669. https://doi.org/10.1111/j.1399-3054.2007.01008.x

SRDI, 2010. SRMAF Project. Soil Resource Development Institute. Ministry of Agriculture GoB.

Yeo, A.R., Lee, K.S., Izard, P., Boursier, P.J. and Flowers, T.J., 1991. Short-term and long-term effects of salinity on leaf growth in rice (*Oryza sativa* L). *Journal of Experimental Botany*, 42: 881–889. https://doi.org/10.1093/jxb/42.7.881

Yoshida, S., Forno, A.D., Cock, J.A. and Gomez, K.A., 1976. Physiological Studies of Rice. 2nd Eds. Int. Rice Res. Inst., Manila, Philippines.

Zelelew, D.Z. Lal, S., Kidane, T.T., and Ghebreslassie, B.M. 2016. Effect of potassium levels on growth and productivity of potato varieties. *American Journal of Plant Science*, 7: 1629–1638. https://doi.org/10.4236/ajps.2016.712154