Effect of Salinity and Alleviating Role of Gibberellic Acid (GA_3) for Enhancement of Rice Yield

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***Abstract*—**Salinity affects rice crop from sowing to harvesting; subsequently the rice area and production is decreasing with passage of time. The effect of salinity on rice and salinity relieving role of GA_3 (150 ppm) was observed on two salt tolerant rice cvs. (Pokkali and MR219) grown in various salt concentration (0, 50, 100, 150 and 200 mM) in glass house condition. A unit increase in salt concentration significantly decreased important yield components and consequently grain yield. Plants of MR219 grown in severe salinity stress (150 and 200 mM) could not initiate/form panicles and thus grains. However, Pokkali showed tolerance but, recorded low number of panicles and filled grains. Therefore, in the severe saline condition, GA_3 could not play its salinity alleviating role, whereas, its impact was consistent in moderate salinity stress (50 and 100 mM).

***Keywords*—**Hormone, GA_3, Rice, Salinity

I. Introduction

SALINITY is becoming a serious problem in several parts of the world limiting the productivity of agricultural crops. Total area under salinity is about 953 million ha covering about 8 percent of the land surface [1]. Approximately 6% of the world's land area, which is equivalent to 800 million hectares, is affected either by salinity or sodicity, Thus, it is contributing 3 hectares of additional arable land each minute worldwide [2]. In addition, salinity affects 20% of the world's irrigated land, which accounts for one-third of the world food production [3]. This progressive loss of arable land has potentially serious consequences for the expanding global population, which is steadily increasing towards seven billion, and set to increase by a further 50% by 2050 [4].

In salt affected soils, especially NaCl readily dissolves in water to yield the toxic ions, sodium (Na^+) and chloride (Cl^-) through inducing osmotic stress [5]. Salinity and sodicity can reduce plant growth and alter ionic relations by ionic osmotic effects and oxidative stress [6]. The reduced water potential in saline habitat creates the plant a two-edged problem: a corresponding water and ion stress.

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The salt-resistant species often possess special features to remove NaCl from the cytoplasm [7], uptake, accumulation of Na^+ and Cl^- into the different plant organs is highly controlled [8]. Rice (*Oryza sativa* L.) is a salt sensitive monocot [9] and widely grown crop in tropical and subtropical regions [10]. It is one of the main staple foods for nearly two-thirds of the population of the world [11]. With the rapid growth in population, high rice consumption, degradation of soil and water quality around the globe have focused urgent attention to understand the response of this important crop towards abiotic stresses e.g salinity which is directly related in reduction of its yield [12]. The harmful effects of salinity could be corrected by treating plants improve crop performance under normal conditions.

A few studies have, however, demonstrated the ability of GA_3 to overcome adverse effects of NaCl stress [14]. This research, therefore, was conducted to determine how GA_3 and salt tolerant rice cultivars can alleviate the adverse effects of varying salt concentrations for the enhancement of rice yield.

II. Material and Methods

The study conducted at the glasshouse, Universiti Putra Malaysia during 2010-2011. The two salt tolerant rice cvs. (Pokkali and MR219) were treated with GA_3 (150 ppm foliar spray) under five salinity levels (0, 50, 100, 150 and 200 mM). Earthen pots (24.5cm dia. and 28cm depth) were filled with 10 kg plough layer brought from rice growing area of Perak, Malaysia. Five seedlings at the age of 22 days were transplanted in each pot. After two weeks of transplanting, the solutions of 50 to 200 mM NaCl were applied and renewed after every 2 days. However, control (0 mM) received tap water. Two weeks after the inception of the salinity treatments, plants were sprayed with GA_3 @ 150 ppm mixed with Tween-20 (0.1%) as the surfactant at 5 pm to avoid evaporation. The soil was prior mixed thoroughly with urea, triple supper phosphate (TSP) and muriate of potash (MOP) @ 120, 70, and 80 kg ha^{-1} respectively. Whole TSP and MOP, and ¼th urea were added during the pot preparation. The remaining urea was split applied during 3-leaf, active tillering, booting and heading stages. At harvest of crop, total number of tillers, panicles, filled and unfilled grains per panicle were counted. Same plants were used for panicle length, which was measured through measuring scale. The filled, unfilled and 1000 grains were determined by weighing them on digital top loading balance. The panicles were threshed for the determination of grain yield per pot. The statistical analyses were performed using variance technique and LSD test at P≤ 0.05 to compare the differences among treatments means [15], using Statistical Analysis System software version 9.2.

III. Results and discussion

Panicles per plant: The comparison among the cultivars shown severe effect of higher salt concentration (150-200 mM) and cultivars MR219 was not able to produce panicles, whereas, Pokkali recorded few panicles. In non-saline or low saline condition (50 mM), both the cultivars had better performance. Correlation between different salt concentrations and GA_3 treatment showed more number of panicles per plant in GA_3 treated plants. The decreasing trend in panicles per plant was observed noted with a unit increase in salt concentration without GA_3 treatment. The trend analysis indicated salinity alleviating role of GA_3 treatment and it was consistent in response to salt concentrations (Table 1a & Fig. 1-i). As observed in this study, no panicle initiation occurred in MR219 due to severity of salt stress, which might be due to reduction in foliage and transportation of total assimilates to the growing region. Due to the differential competition in carbohydrate supply between vegetative growth and its low distribution to the developing panicles [16], reduced viability of pollen under stress condition, thus resulting failure of seed set [17]. Before the appearance of panicle, salinity affected the number of tillers and thus, influenced the number of panicle and weight from the period of three leaves to booting [18]. Kiani *et al*. [19] reported that water or soil salinity affected plant's function (production), the number of panicle per square meter, the weight of thousand grains, the number of grains within panicles and also harvest index.

Panicle length (cm): The effectiveness of different salt concentration significantly reduced panicle length of MR219 and Pokkali. Compared to control (tap water), the rice cultivars grown in saline condition (50 and 100 mM) reduced panicle length of MR219. However, Pokkali had satisfactory length of panicles in 150 and 200 mM salt concentrations. It has also been reported that if any cultivars is salt sensitive, then panicle length is significantly reduced [20]. Correlation between different salt concentrations and GA_3 treatment showed declined trend of panicle length in high salt concentration although GA_3 treatment was applied (Table 1a & Fig. 1-ii). There is strong evidence that different concentrations of GA_3 are required at different stages of plant growth during the plant life cycle [21].

Filled and unfilled grains per panicle: The results for filled and unfilled grains per panicle showed that the plants grown in tap water or in 50 mM salt concentration equally produced higher filled grains in MR219 grown. Salt concentration beyond 100 mM inhibited reproductive stage of MR219 and plants could not form panicle and thus filled grains. Similar situation was observed in Pokkali. In contrast, unfilled grains were higher in higher salt concentration in both the cultivars. Correlation analysis showed declined trend in filled grains and inclined trend in unfilled grains with a unit increase in salt concentration. GA_3 treatment enhanced filled grains per panicle. The reason for non-formation of more unfilled grains might be effect of high salt concentration which had adverse effect on pollen formation. In this case, GA_3 showed an alleviating effect over salt concentrations, but its response was upto 100 mM salt concentration (Table 1a & Fig. 1-iii; iv). Similarly, adverse effects of salinity on the number of filled panicle were reported by several researchers [22; 23; 24; 19]. Plant grown in salt stress conditions, the thickness of assimilate conducting pathway is reduced [13], and leaves start behaving as sinks rather than sources [25]. This causes inhibition of assimilate movement towards the developing reproductive organs, which might be the reason for decrease in filled grains per panicle. On the other hand, these adverse effects of high salinity were alleviated by the hormone treatment, primarily by rejuvenation of the sink potential and enhancement of the duration or rate of dry mass accumulation in developing reproductive organs [26]. Regarding role of GA_3, Islam *et al*. [27] also reported that it increased the number of normal kernels percentage. The reason might be the longer functionality of the vascular bundles in different parts of the panicle, which have resulted in an efficient translocation of photosynthates to grain formation [28].

Weight of filled and unfilled grains: In MR219 no data could be record due non-formation of panicles in the plants grown in 150 and 100 mM salt concentration. However, both MR219 and Pokkali recorded higher weight of filled grains per panicle when plants received tap water followed by 50 mM salt concentration. However, further increase in salt concentration (150-200 mM) significantly diminished weight of filled grains and increased weight of unfilled grains. Correlation studies for weight of filled grains per panicle showed declined trend in weight of filled grains with more weight of unfilled grains with the unit increase in salt concentration. GA_3 treatment has salinity alleviating role and was consistent with various salt concentrations and supported plants to record increased weight of filled grains in the panicles (Table 1b & Fig. v; vi). Zeng and Shannon [12] also reported that salinity significantly affected weight of grain per panicle. Clermont-Dauphin *et al*. [29] were also in the view that the number and weight of filled grains per panicle are most sensitive yield components to salinity. Similarly, Mohamood *et al*. [30] observed that increasing salinity significantly reduced grain filling capacity. In addition of pollen’s lifetime, its fertility decreases significantly due to salinity. These results agree with the results of Davies [26] and Magome *et al*. [31] stating that GA_3 mediated increase in the number of grains. They have also demonstrated the involvement of gibberellins in the induction and promotion of flowering in many plants.

1000 grain weight: The GA_3 treatment applied in 50 and 100 mM salt concentration had more weight of 1000 grains. However, plant grown without GA_3 showed decreasing trend of 1000 grain weight. The GA_3 line also indicated an alleviating effect over different salt concentrations and supported plants to record higher weight of 1000 (Table 1b & Fig. 2.vii). High influence of salinity on the weight of 1000 kernels was reported by several researchers [32; 23; 33]. Similar results were also found by Kiani *et al*. [19]. that water or soil salinity reduced 1000 grain weight to some extent in 50 and 100 mM salt concentrations. In this study, GA_3 treatment in saline condition showed salinity relieving impact and increased the weight of 1000 grains of both MR219 and Pokkali. Similarly, Liuling *et al*. [34] reported that a 60 mg/L GA_3 spray to wheat plants increased grain weight.

Grain yield per pot: Salinity stress severely affected grain yield of both rice cultivars. Among the tested cultivars, Pokkali significantly recorded higher grain yield in tap water, followed by 50 mM salt concentration treatment in the same cultivar. An increase in salt concentration beyond 100 mM, no grain yield was found due to non-formation of grains in the panicles in MR219. This condition appeared in Pokkali grown in 200 mM salt concentration. Correlation between GA_3 and varying levels of salt concentrations recorded declined tendency in grain yield with a unit increase in salt concentration. In saline conditions (50 mM), GA_3 treatment showed higher grain yield per pot. Further increase in salt concentration (100 to 200 mM) showed sharp decline in grain yield per pot, even though plants were treated with GA_3. The zero grain yield was observed in high salt concentration (200 mM) with or without GA_3 treatment, which might be due to non-formation of filled grains in the panicles and thus grain yield record was zero (Table 1b & Fig. 2-viii). The non-significant influence of GA_3 treatment in all the salt concentration treatments was observed in both MR219 and Pokkali rice cultivars. Although, the interaction of GA_3 x salt concentrations was non-significant, but GA_3 treatment in different salt concentrations slightly increased grain yield due to it salinity alleviating effect. Salt tolerance of plants are assessed either by the percent biomass production or by grain yield in saline versus control conditions over prolonged period of time [35].Developing salinity tolerance rice varieties is very important approach not only for increasing yields, but also for conquering saline soils [36].The high levels of salts can restrict or even scupper the rice cultivation, also by the presence of some elements in toxic concentrations [37]. In this study, decrease in grain yield could be predicted due to reduction in all the yield components. Zeng *et al*. [22] also found that in saline condition, grain yield per plant was reduced primarily by a reduction in number of tillers per plant, number of spikelets per panicle, and the grain weight per panicle. Mahmood *et al*. [30] observed that increasing salinity significantly reduced the grain filling capacity, and thus a significant reduction in grain yield was noted. Reports are available stating that salinity is a serious concern for plant stand and the development of yield components [12]. Salinity decreases number of grains in panicle and harvest index by diminishing grain yield [23]. Kumar and Singh [38] also reported a decrease in growth and grain yield due to salt stress, but GA_3 treatment increased both the growth and grain yield under salt stress.

IV. Conclusions

Salinity stress significantly affected yield components and ultimately yield. The severe salinity stress (150 and 200 mM) inhibited most of the important yield components like panicle and grain number and thus plants were not able to initiate the panicles. In the severe salinity condition, GA_3 also could not play its salinity alleviating role. However, both MR219 and Pokkali tolerated moderate salinity (50 and 100 mM) and application of GA_3 performed better in recording higher grain yield.

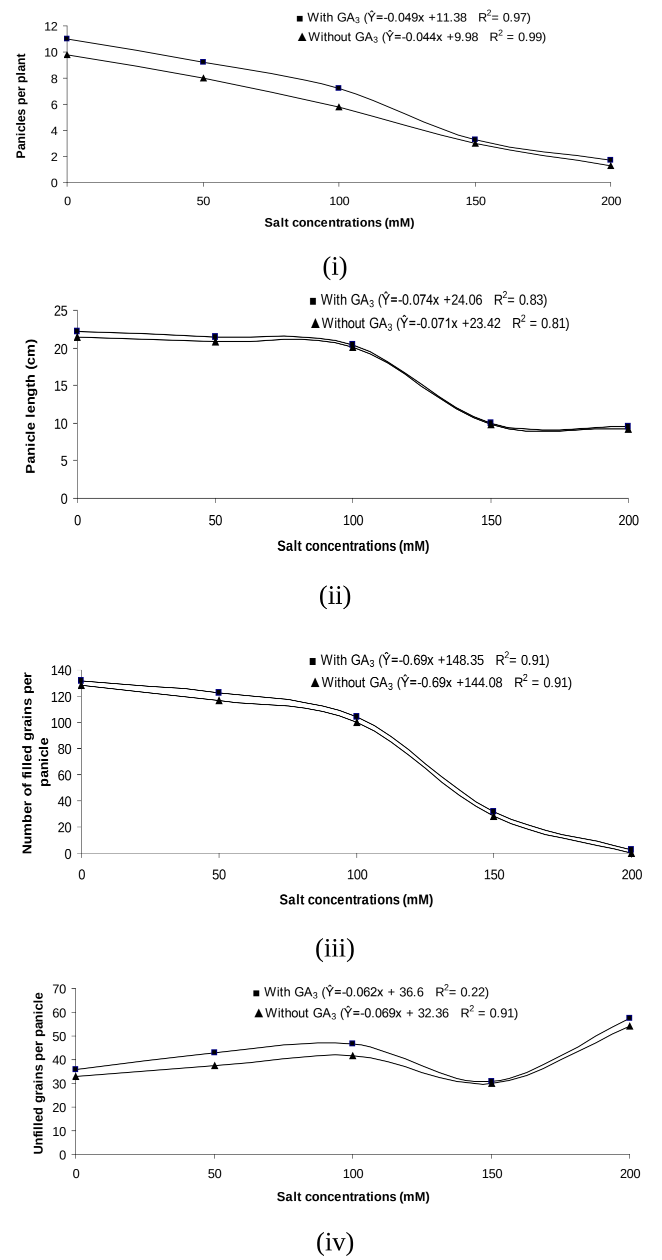

Fig. 1. Relationship between salt concentrations and salinity alleviation role of GA_3 treatment for (i) tillers per plant, (ii) panicle length (cm), (iii) number of filled grains per panicle, and (iv) number of unfilled grains per panicle (pooled across the rice cultivars).

TABLE 1A.
YIELD AND YIELD COMPONENTS OF RICE CULTIVARS UNDER THE INFLUENCE OF SALT CONCENTRATIONS AND GA_3 TREATMENT

Salt conc. (mM) X Cultivar X GA_3 (150 ppm)	Panicles / plant	Panicle length (cm)	Filled grains / panicle	Unfilled grains / panicle
MR219+0+0	9.7 abc	21.3 abc	133.7 a	52.0 b
MR219+0+GA_3	10.7 ab	22.0 á	137.0 a	56.3 b
Pokkali+0+0	10.0 abc	21.6 ab	123.7 abc	14.0 e
Pokkali+0+GA_3	11.3 a	22.5 á	126.7 abc	15.6 d
MR219+50+0	7.0 de	20.3 b-e	126.3 abc	38.3 bc
MR219+50+GA_3	8.3 cd	21.0 a-d	132.3 ab	44.3 b
Pokkali+50+0	9.0 bc	21.6 ab	107.7 cd	37.0 bc
Pokkali+50+GA_3	10.0 abc	21.8 ab	112.0 cd	41.6 b
MR219+100+0	4.5 fg	18.3 f	111.7 cd	42.0 b
MR219+100+GA_3	5.7 ef	19.3 ef	114.7 bc	45.3 b
Pokkali+100+0	7.0 de	21.9 ab	89.00 e	41.3 b
Pokkali+100+GA_3	8.7 c	21.5 ab	94.00 e	48.0 b
MR219+150+0	0.00 i	0.00 g	0.00 g	0.00 d
MR219+150+GA_3	0.00 i	0.00 g	0.00 g	0.00 d
Pokkali+150+0	6.0 ef	19.6 def	56.7 f	59.6 b
Pokkali+150+GA_3	6.7 de	20.0 cde	63.7 f	61.3 b
MR219+200+0	0.00 i	0.00 g	0.00 g	0.00 d
MR219+200+GA_3	0.00 i	0.00 g	0.00 g	0.00 d
Pokkali+200+0	2.2 h	18.4 f	0.00 g	108.7 a
Pokkali+200+GA_3	3.3 gh	19.0 ef	4.68 g	115.3 á
SE	0.5529	0.474	5.834	8.244
LSD 5%	1.580	1.357	16.67	23.56

TABLE 1B
YIELD AND YIELD COMPONENTS OF RICE CULTIVARS UNDER THE INFLUENCE OF SALT CONCENTRATIONS AND GA3 TREATMENT

Salt conc. (mM) X Cultivar X GA_3 (150 ppm)	Wt. of filled grains / panicle (g)	Wt. of unfilled grains / panicle (g)	Seed index (1000 grain wt.) (g)	Grain yield per pot (g)
MR219+0+0	2.487 ab	0.29 a-e	25.3 a	59.3 bc
MR219+0+GA_3	2.820 a	0.33 abc	25.7 a	63.2 bc
Pokkali+0+0	2.350 ab	0.04 ef	23.0 c	198.4 a
Pokkali+0+GA_3	2.760 a	0.07 c-f	24.3 ab	206.7 a
MR219+50+0	2.273 ab	0.32 a-d	21.8 c	56.9 bc
MR219+50+GA_3	2.363 ab	0.42 a	22.6 c	60.6 bc
Pokkali+50+0	1.850 abc	0.05 def	19.3 d	75.1 b
Pokkali+50+GA_3	2.183 ab	0.39 ab	21.7 c	74.6 b
MR219+100+0	2.153 ab	0.14 b-f	18.0 d	20.7 bc
MR219+100+GA_3	2.360 ab	0.20 a-f	19.5 d	25.1 bc
Pokkali+100+0	1.267 c	0.09 c-f	13.9 f	18.5 bc
Pokkali+100+GA_3	1.490 abc	0.15 a-f	16.9 e	25.6 bc
MR219+150+0	0.00 d	0.00 f	0.00 h	0.00 c
MR219+150+GA_3	0.00 d	0.00 f	0.00 h	0.00 c
Pokkali+150+0	0.85 cd	0.13 b-f	7.6 g	4.49 c
Pokkali+150+GA_3	1.06 cd	0.16 a-f	8.9 g	5.84 c
MR219+200+0	0.00 d	0.00 f	0.0 h	0.00 c
MR219+200+GA_3	0.00 d	0.00 f	0.0 h	0.00 c
Pokkali+200+0	0.00 d	0.18 a-f	0.00 h	0.00 c
Pokkali+200+GA_3	0.02 d	0.22 a-f	0.00 h	0.00 c
SE	0.436	0.082	0.603	19.75
LSD 5%	1.246	0.233	1.722	56.44

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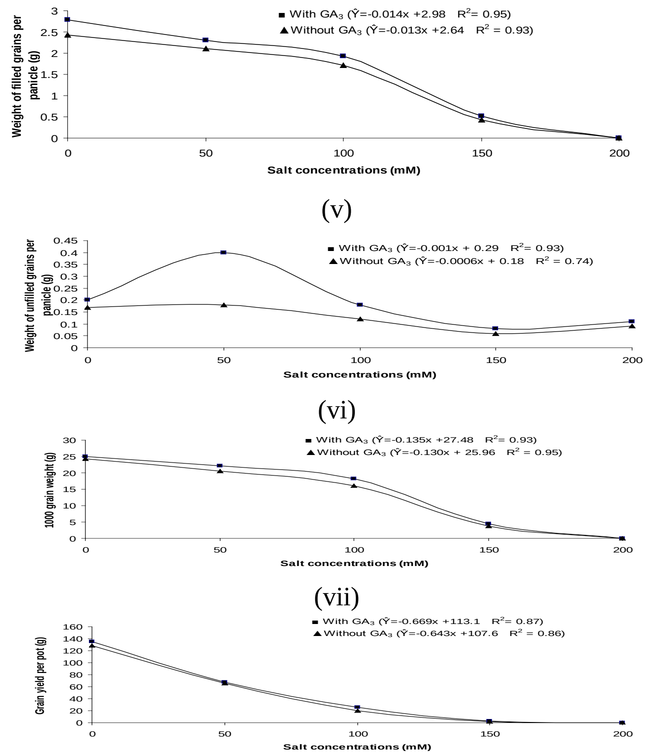

(viii)

Fig. 2 Relationship between salt concentrations and salinity alleviation role of GA_3 treatment for (v & vi) wt. of filled and un filled grains (g) per panicle (vii) 1000 grain wt (g), and (viii) grain yield (g) per pot (pooled across the rice cultivars).

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REFERENCES

[1] G. Singh, "Salinity related desertification and management strategies,". Indian experience. *Land Degrade Develop*., 2009. 20: 367-385.

[2] F.A.O., "Land and Plant Nutrition Management Service. Available online at: http://www. fao.org /ag /agl/agll/spush., 2008.

[3] V. Chinnusamy, A. Jagendorf and J. Zhu " Understanding and improving salt tolerance in plants". Crop Science, 2005, 45: 437-448.

[4] F.A.O. "How to Feed the World in 2050: Technology Challenge. Food and Agriculture Organization (FAO) High-Level Expert Forum, Rome", October 2009. Available online at: http:// www. fao.org/filedmin/templates/wsfs/docs/Issues_ papers /HLEF2050 _Technology.pdf

[5] K. Siringam, N. Juntawong, S. Chaum and C. Kirdmanee "Salt stress induced ion accumulation, ionhomeostasis, membrane injury and sugar contents in salt-sensitive rice (*Oryza sativa* L. *spp*. indica) roots under isosmotic conditions", *Afr. J. Biotech*., 2011, 10: 1340-1346.

[6] G. Eraslan, A. Bilgili, D. Essiz, M. Akdogan and F. Sahindokuyucu. " The effects of deltamethrin on some serum biochemical parameters in mice". *Pestic. Biochem. Phys.*, 2007, 8: 123-130.

[7] H.W. Koyro, "Effect of salinity on growth, photosynthesis, water relations and solute composition of the potential cash crop halophyte *Plantago coronopus* (L.)" *Env. & Exp. Bot.*, 2006,56: 136-146.

[8] P.M. Hasegawa, R.A. Bressan, J.K. Zhu and H.J. "Bohnert. Plant cellular and molecular responses to high salinity", *Annu. Rev. Plant Mol. Plant Physiol.*, 2000, 51: 463-499.

[9] E. Darwish, C. Testerink, M. Khalil, El-Shihy and T. Munnik. "Phospholipid signaling responses in salt-stressed rice leaves". *Plant Cell Physiol.*, 2009, 50: 986-997.

[10] A. K. Singh, N. Chandra and R.C. Bharati. "Effects genotypes and planting time on phenology and performance of rice (*Oryza sativa* L.)". *Vegetos*. 2012, 25: 151-156.

[11] A.K.D. Roy, K. Alam and J. Gow. "A review of the role of property rights and forest policies in the management of the Sundarbans mangrove forest in Bangladesh." *Forest Policy Econ.*, 2012, 15: 46-53.

[12] L. Zeng and M.C. Shannon, "Effects of salinity on grain yield and yield components of rice at different seeding densities". *Agron. J.*, 2000a, 92: 418-423.

[13] H.S. Aldesuquy and A.H. Ibrahim. "Interactive effect of seawater and growth bio-regulators on water relations, absicisic acid concentration, and yield of wheat plants". *J. Agron. Crop. Sci.*, 2001, 187: 185-193.

[14] N. Chakraborti and S. Mukherji. "Effect of phytohormone pre-treatment on nitrogen metabolism in *Vigna radiata* under salt stress". *Biol.Plant.*, 2003 46: 63-66.

[15] R.G.D. Steel, J.H. Torrie and D.A. Dickey. "Principles and procedures of statistics. McGraw-Hill" New York: 1997.

[16] P.S.S. Murty and K.S. Murty. "Spikelet sterility in relation to nitrogen and carbohydrate contents in rice". *Indian J. Plant Physiol.*, 1982, 25: 40-48.

[17] Z. Abdullah, M.A. Khan and T.J. Flowers. "Causes of sterility in seed set of rice under salinity stress". *J. Agron. & Crop Sci.*, 2001, 187(1): 25.

[18] L. Zeng, S.M. Lesch and C.M. Grieve. "Rice growth and yield respond to changes in water depth and salinity stress". *Agr. Water Manage.*, 2003, 59: 67-75.

[19] A.R. Kiani, M. Homaee and M. Mirlatifi. "Evaluating yield reduction functions under salinity and water stress conditions". *Iranian J. soil and Water Sci.*, 2006, 20:73-83.

[20] A. Shereen, S. Mumtaz, S. Raza, M.A. Khan and S. Solangi." Salinity effects on seedling growth and yield components of different inbred rice line". *Pak. J. Bot.*, 2005 37: 131-139.

[21] N. Takahashi, "Gibberellins in regulation of the life cycle of plants". *Proc. Plant Growth Regul. Soc. Am.*, 1992, 19: 1-8.

[22] L. Zeng and M.C. Shannon, "Salinity effects on seedling growth and yield components of rice". *Crop Sci.*, 2000b, 40: 996-1003.

[23] G. Beatriz, N. Piestun and N. Bernstein."Salinity-induced inhibition of leaf elongation in maize mediated by changes in cell wall". *Plant Physiol*, 2001, 125:1419-1428.

[24] L. Zeng, S.M. Lesch and C.M. Grieve, "Rice growth and yield respond to changes in water depth and salinity stress". *Agri. Water Manage.*, 2003,5 9: 67-75.

[25] V. Arbona, A.J. Marco, D.J. Ijlesias, M.F. Lopez-Climent, M. Talon and A. Gómez-Coudenas, "Carbohydrate depletion in roots and leavers of salt stressed potted *Citrus clemtina* L". *Plant Growth Regul.*, 2005, 46: 153-160.

[26] P.J. Davies, "Plant hormones: Physiology, biochemistry, and molecular biology". *Kluwer Academic Publishers, London*, 1995, pp 6-7.

[27] M.S. Islam, G.J.H. Ahmad and Zulfiquar, "Effect of flag leaf clipping and GA_3 application on hybrid rice seed yield". *IRRN.*, 2005, 30: 46-47.

[28] I.U. Awan, M.S. Baloch, M.Z. Saddozai and M. Sulemani, "Stimulatory effects of GA3 and IAA on ripening process, kernel development and quality of rice". *Pak. J. Biol. Sci.* 1999, 2: 410-412.

[29] C. Clermont-Dauphin, N. Suwannang, O. Grünberger, C. Hammecker and J.L. Maeght. "Yield of rice under water and soil salinity risks in farmers fields in Northeast Thailand". *Field Crops Res.*, 2010, 118: 289-296.

[30] A. Mahmood, T. Latif and A.M. Khan, "Effect of salinity on growth, yield and yield components in Basmati rice germplasm". *Pak. J. Bot.*, 2009, 41: 3035-3045.

[31] H. Magome, S. Yamaguchi, A. Hanada, Y. Kamiya and K. Oda, "Dwarf and delayed-flowering, a novel Arabidopsis mutant deficient in gibberellin biosynthesis because of over expression of a putative AP_2 transcription factor". *Plant J.*, 2004, 37: 720-729.

[32] F. Asch, M. Dingkuhn and K. Doerffling. "Salinity increases CO_2 assimilation but reduces growth in field-grown irrigated rice". *Plant Soil*, 2000, 218: 1-10.

[33] S. Saadat, M. Homaee, A.M. Liaghat. "Effect of soil solution salinity on the germination and seedling growth of sorghum plant". *Iranian J. Soil and Water Sci.*, 2005, 19(2): 243-254.

[34] Y. Liuling, Y. Gowenshan, F. Chaunian, P.Y Xin, Z.X. Kai and Z.Z. Xing, "Studies on the grain volume and degree on the filling in wheat". *Acta Agron. Sinica*. 1995, 21:637-640.

[35] R. Munns, S. Husain, A.R. Rivelli, R.A. James, A.G. Condon, M.P. Lindsay, E.S. Lagudah, D.P. Schachtman and R.A. Hare, "Avenues for increasing salt tolerance of crops, and the role of physiologically based selection traits". *Plant & Soil*. 2002, 247: 93-105.

[36] A.A. El-Mouhamady, I.S. El-Demardash and K.A. Aboud. "Biochemical m and molecular genetic studies on rice tolerance to salinity". *J. Am. Sci.*, 2010, 6: 521-535.

[37] T.I. Fraga, F.C. Carmona, I. Anghinoni, S.A.G. Junior and E. Marcolin. "Flooded rice yield as affected by levels of water salinity in different stages of its cycle". *R. Bras. Ci. Solo.*, 2010, 34: 175-182.

[38]. B. Kumar and B. Singh. "Effect of plant hormones on growth and yield of wheat irrigated with saline water". *Annu. Agr. Res.*, 1996, 17: 209-212.