



Full Length Article

Growth and Yield Response of Rice (*Oryza sativa*) to Different Seed Coating Agents

MITHAT NURI GEVREK¹, GÜLDEN DENİZ ATASOY AND ALI YIGIT
Ege University, Faculty of Agriculture, Department of Field Crops, Turkey
¹Corresponding author's e-mail: mithat.gevrek@ege.edu.tr

ABSTRACT

The effect of some materials on the rice growth was examined using the film coating technique without changing the shape of the seed. The trial was conducted in Gonen during 2010 and 2011 and the experiment was set up as randomized complete block design with four replications. The variety "Osmancik-97" was the plant material of the study. Seed coating treatment was performed with the lab type film coating equipment. The treatments included were as seed coating with KNO₃ (2000 & 4000 mg/L) and GA₃ (1000 mg/L) including control. According to the mean values of two years, the highest values for effective tillers (6.8 plant⁻¹), number of fertile grains (630 plant⁻¹) and grain yield (2010: 23.2 g plant⁻¹ & 2011: 19.3 g plant⁻¹) were obtained from the treatment 1000 mg/L GA₃. Also, the highest germination rate (89.6%) was found in the treatment 1000 mg/L GA₃. In the year 2011, the difference between the treatments was statistically significant for the parameters root dry matter (1000 mg/L GA₃: 0.037 g), leaf dry matter (1000 mg/L GA₃: 0.073 g) and total biomass (1000 mg/L GA₃: 0.109 g) of three week old seedlings. According to these results, it is indicated that vigorous seeds, seedlings and high yields could be successfully obtained with the application of 1000 mg/L GA₃ using the film coating technique. © 2012 Friends Science Publishers

Key Words: Rice; Seed coating; GA₃; KNO₃

INTRODUCTION

Seed coating involves application of required materials to the seed-soil interface and the method allows using minor amounts of materials to affect micro environment of each seed. Seed coating practices have recently become the most studied area with its benefits of reducing costs and increasing the efficiency of the materials (Subbaih & Mitra, 1997; Zeng & Shi, 2008; Tiwari *et al.*, 2011).

Producers mostly prefer using pesticides, herbicides and fertilizers to cope with the negative factors which occur during the growing period. However, these practices are generally too expensive and critical financial losses come out in case of probable mistakes. To support plant growth, seed coating is pronounced as an alternative solution (Zelonka *et al.*, 2005; Farooq *et al.*, 2009; 2010; Zeng *et al.*, 2010).

The technique is widely used in Europe, USA and Australia to ameliorate germination, coping with pests and diseases besides applying necessary micro elements to the plant. Several studies report seed coating effects on improved seedling and root growth and an increase in yield (Subbaih & Mitra, 1997; Zeng & Shi, 2008; Tiwari *et al.*, 2011).

Early, in high ratio and fast germination is desired for rice seed on the field conditions. On the other hand,

obtaining high germination performance, vigorous seedling growth and high yielding capacity under improper stress conditions such as low and high temperatures, soil salinity and clay soil are also important for the quality of the seed (Scott, 1989; Zhang *et al.*, 2007). For this research, film coating technique is preferred among different coating methods. Additional chemicals are applied to the coated seeds before sowing to improve the yield capacity.

Tiwari *et al.* (2011) studied with 34 treatment combinations of different growth regulators on hybrid rice seed production in 2001-2002 and 2002-2003. The results indicated that the analysis of various plant growth hormones significantly increases seed yield with a range of 14.85 g to 23.54 g. Treatment of GA₃ 45 g + C.C. had highest significant increase in grain yield followed by GA₃ 45 g, GA₃ 30 g, NAA 200 g, NAA 100 g, Urea 2 g + C.C. and GA₃ 45 g + K₂PO₄ 2 g. The other yield components showed also a significantly increases with the foliar application of growth regulators.

Therefore, it is expected to save from additional fertilizer with application of plant nutrients. Also addition of gibberellins provides the plant with homogenous germination, saving from the seed amount, plant growth with high performance, increased tillering, high quality and yield (Frankenberger & Arshad, 1995; Subbaih & Mitra, 1997; Elankavi *et al.*, 2009; Tiwari *et al.*, 2011).

This study is aimed to examine the effects of growth promoters and chemicals on germination performance, seedling development, yield, morphological and phenological characteristics of rice using the seed coating technique.

MATERIALS AND METHODS

The rice variety "Osmancık-97", which is defined as middle early, medium height and high yielding, was used as plant material in this study (Sürek, 2002).

Seed coating was performed with the lab type of film coating equipment. Rice seeds were coated with coloring polymer solution and KNO_3 or GA_3 as defined by ISTA to encourage the germination of the seeds. Different treatments were control, 2000 and 4000 mg/L KNO_3 and 1000 mg/L GA_3 (ISTA, 2006).

Germination tests were performed on the treated and control seeds to determine the effects of seed coating on germination rate and seed vigor. After seed coating field study was conducted during the 2010 and 2011 in Gönen, Turkey. Sowing dates for both seasons were adjusted according to climatic and soil conditions. During the first year, crop was sown on 3rd week of May, 2010, while because of the excessive precipitation in April (85.6 mm) and May (33.4 mm) during second year, the sowing of rice was performed in the middle of June, 2011 (Table I).

The soil texture of the experimental site was determined as sandy clay loam with 6.72 pH. The total soluble salt content of the soil was 0.050% approximately and the soil was defined as not salty. The content of organic matter was 1.34%, defined as low. Total lime content of the soil was also low (0.94%). Total nitrogen content of the soil was in medium level and total phosphor content was low. Total potassium content of the soil was determined as sufficient (Table II).

The experiment was set up as randomized complete block design with four replications. Sowing was done in the paddies with the size of 18 m² (6 m × 3 m) each separated by 40 cm height ridge. Each replication with the size of 4 × 18 m² = 72 m² includes four different treatments and the total area of the trial was 288 m².

The seeds were sown directly at a density of 180.0 kg germinating seed ha⁻¹ (Kün, 1985; Beşer, 2000; Sürek, 2002).

During soil preparation N, P, and K fertilizers were applied and incorporated in the soil. 60 kg^{-ha} mineral nitrogen in NH_4^+ form was given as Ammonium Sulfate repeated in three times; namely during sowing, before tillering and one week before flowering duration (Sims *et al.*, 1968; Kün, 1985; Beşer, 2000). Phosphate and potassium requirement of plants were met from 80 kg^{-ha} (P_2O_5) as Triple Super Phosphate and from 40 kg ha⁻¹ (K_2O) as Potassium Sulfate commercial fertilizers, respectively (Sims *et al.*, 1968; Kün, 1985). Weed control was managed by using herbicides containing propanil. Water supply was

ended in the sub-plots 20 days before harvesting. Harvest was done by using sickles.

The effects of seed coating treatments were evaluated on seedling development, yield, yield components and other characteristics. The following characteristics yield (g plant⁻¹), sterility rate (%), 1000-grain weight (g) and on the 3-week-old seedlings; plant height (cm), root weight (g plant⁻¹), leaf weight (g plant⁻¹) and biomass (root & leaf weight) (g plant⁻¹) were recorded (IRRI, 1998).

The ecological conditions of Gonen and the meteorological conditions of the growing seasons 2010 and 2011 are given in Table I.

All data were analyzed by using standard ANOVA techniques of computer program. The means were compared by using the LSD test described by Steel and Torrie (1980).

RESULTS AND DISCUSSION

The effect of the years was found statistically not significant for 1000-grain weight, sterility rate, germination rate and flowering duration, but it was found statistically significant in the yield, fertile tillering, full grain, plant height and panicle length parameters. As to the effect of the treatments, it was found statistically not significant for 1000-grain weight, panicle length and flowering duration while it was found statistically significant for yield, fertile tillering, full grain, plant height, sterility rate and germination rate. The interaction of year and treatments was found statistically significant in case of grain yield (Table III).

The grain yield value was 20.43 g plant⁻¹ in the first year, in the second year it was 5.28 g plant⁻¹ lower than the first year and was found as 15.15 g plant⁻¹. In both years, the grain yield of the treatments was higher than control. Among treatments, the yield value of 1000 mg/L GA_3 was highest, followed by the treatment 4000 mg/L KNO_3 . Xu and Li (1988) and Tiwari *et al.* (2011) also reported significant increases of grain yield with GA_3 treatments.

The effect of treatments was found statistically significant in tillering efficiency and numbers of full grain, which are considered as important yield components. Numbers of productive tillers were found highest (6.8) in the 1000 mg/L GA_3 treatment. The highest values for the parameter numbers of full grain were obtained from the treatments 1000 mg/L GA_3 (630.3) and 4000 mg/L KNO_3 (618.3) respectively (Table IV). The values for 1000-grain weight varied between 31.03 g and 33.76 g during the years; however the difference between the years and treatments was not found statistically significant (Table III).

The study was conducted in the first year (2010) in the 3th week of May but because of the excessive precipitation in April (85.6 mm) and May (33.4 mm), the sowing of rice could be performed in the middle of June in the second year (2011) (Table I). Thus, the delayed sowing time of the second year caused a reduction of the mean values of three parameters compared to the first year (Table IV).

Numbers of productive tillers and fertile grains are known as primary yield components, which also play an important role in yield formation. For both characteristics, the treatment 1000 mg/L GA₃ had a better performance compared to the other treatments. If the values for yield formation are examined on Table IV, it is observed that the mean yield has been also the highest in the treatment 1000 mg/L GA₃. Subbaih and Mitra (1997), Elankavi *et al.* (2009) and Tiwari *et al.* (2011) also reported a significant difference for the fertile tillers and numbers of spikelet's with 1000 mg/L GA₃ treatment, which could be a reason of a positive effect on the yield.

The mean plant height value for two years was found 83.3 cm, as it was 86.9 cm in the first year and 79.7 cm in

Table II: Physical and chemical properties of experimental site after harvest

Soil characteristics	Values
pH	6.72
Total salt (%)	0.05
Lime (%)	0.94
Soil texture	Clay loam
Organic matter (%)	1.34
Total nitrogen (%)	0.07
Available phosphorus (ppm)	4.28
Available potassium (ppm)	278
Available calcium (ppm)	1210
Available magnesium (ppm)	160
Available sodium (ppm)	47
Available iron (ppm)	12.8
Available zinc (ppm)	1.18
Available copper (ppm)	3.2

The mean value of spikelet length was 16.28 for two growing seasons. It was found 15.5 cm in the first year and 17.0 cm in the second year as being 1.5 cm taller than the first year. So the difference between the two years was found statistically significant while the difference between the treatments was not found significant.

The number of the days from sowing until flowering of the plants reaches a rate of 50% was calculated as flowering duration. The mean value of flowering duration was found 84.3 and the values varied between 80 and 88. The effect of different treatments on flowering duration was not found statistically significant.

When the results for the parameter sterility rate are examined, it is seen that the difference between the years was not statistically significant as the difference between the treatments was statistically significant. The sterility rate of the control (31.39%) was higher than all the treatments' and the lowest sterility rate belong to 4000 mg/L KNO₃ treatment (Table IV).

Nanda (1979) underlined that during critical periods, flowering and fertilization plants are more susceptible to high temperatures and such an effect causes high sterility. It is seen on table II that the highest temperature reaches to 37.1°C during August, the flowering period and it was 32.9°C in the second year. So the sterility rate value of the first year (17.2%) was higher than the second year (15.6%).

The difference between the years was not found statistically significant for the characteristics germination

Table I: Average temperatures (°C), Average relative humidity (%) and Monthly total rainfall (mm) at Gönen in 2010 and 2011

Years		Months					
		April	May	June	July	August	September
2010	Maximum monthly air temp. (°C)	28.0	35.0	35.7	33.4	37.1	*
	Minimum monthly air temp. (°C)	0.8	3.1	12.1	16.2	15.7	*
	Average monthly air temp. (°C)	12.6	18.5	22.4	24.9	26.8	*
	Average relative humidity (%)	78.0	*	71.3	71.5	69.2	*
	Monthly total rainfall (mm)	74.6	29.1	132.0	37.6	0.4	*
2011	Maximum monthly air temp. (°C)	24.9	30.3	37.0	36.9	32.9	*
	Minimum monthly air temp. (°C)	-0.2	1.9	9.8	13.6	12.6	*
	Average monthly air temp. (°C)	10.1	16.4	21.9	25.6	23.5	*
	Average relative humidity (%)	79.3	76.1	66.7	62.6	64.7	*
	Monthly total rainfall (mm)	85.6	33.4	33.9	2.8	1.4	*

* No observation

the second year, which is 7.2 cm shorter than the first year. The plant height of the control was shorter than all the treatments whereas the value of 1000 mg/L GA₃ treatment was observed as the highest (87.4 cm). The most important effect of gibberellins on the plant growth is known as the increase in the stem length. They trigger cell division and stem elongation. Taller plant height values of 1000 mg/L GA₃ treatment could be explained with these characteristics of gibberellins. Dunand (1998), Peng *et al.* (1999), Richards *et al.* (2001), Itoh *et al.* (2001) and Sun (2004) also point out that gibberellins are major factors on stem elongation.

rate as the difference between the treatments was statistically significant. While the germination rate of treatments was higher than the control, the highest performance (89.6%) belongs to the 1000 mg/L GA₃ treatment (Table IV). Gibberellins facilitate germination process as providing formation of alfa-amylase enzyme which hydrolyzes the starch and transformation of starch to the sugar compounds, which could be used easily by embryo (Dunand, 1993). The positive effect of gibberellins on germination could be the reason of high germination rate values of 1000 mg/L GA₃ treatment.

Table III: Results of analysis of variance combined across years and treatments to both years (2010-2011)

	Yield (g plant ⁻¹)	Tillering (number plant ⁻¹)	Full grain (number plant ⁻¹)	1000 grain weight (g)	Plant height (cm)	Panicle length (cm)	Flowering duration (days)	Sterility rate (%)	Germination rate (%)
Year	349.948**	25.170**	25.860**	ns	49.940**	51.465**	ns	ns	ns
Treatment	112.935**	23.184**	30.966**	ns	16.809**	ns	ns	179.424**	40.00**
Year x Treat.	5.39**	ns	ns	ns	ns	ns	ns	ns	ns

** Significant at 1% level

Table IV: The effect of seed coating technique on yield, yield components and some characteristics of rice at Gönen, in 2010-2011

Character	Treatments	Year I	Year II	Mean
Yield (g plant ⁻¹)	KNO ₃ (2000 mg/L)	20.1 B	13.1 C	16.6
	KNO ₃ (4000 mg/L)	21.3 B	16.3 B	18.8
	GA ₃ (1000 mg/L)	23.2 A	19.3 A	21.2
	Control	16.8 C	11.7 C	14.3
	Mean	20.3	15.1	17.7
	LSD (%5): 0.849			
Tillering (number plant ⁻¹)	KNO ₃ (2000 mg/L)	6.3	5.0	5.6 B
	KNO ₃ (4000 mg/L)	6.6	5.3	6.0 B
	GA ₃ (1000 mg/L)	7.3	6.3	6.8 A
	Control	4.6	4.0	4.3 C
	Mean	6.2	5.1	5.7
	LSD (%5): 0.655			
Full grain (number plant ⁻¹)	KNO ₃ (2000 mg/L)	605.0	549.1	577.0 B
	KNO ₃ (4000 mg/L)	650.0	586.7	618.3 A
	GA ₃ (1000 mg/L)	671.3	589.3	630.3 A
	Control	504.6	463.3	484.0 C
	Mean	607.5	547.1	577.4
	LSD (%5): 36.179			
1000 grain weight (g)	KNO ₃ (2000 mg/L)	33.7	33.1	33.4
	KNO ₃ (4000 mg/L)	32.4	31.6	32.0
	GA ₃ (1000 mg/L)	32.3	32.0	32.1
	Control	32.5	31.0	31.7
	Mean	32.7	31.9	32.3
	LSD (%5): 1.360			
Plant height (cm)	KNO ₃ (2000 mg/L)	86.1	80.5	83.3 B
	KNO ₃ (4000 mg/L)	89.1	80.7	84.9 AB
	GA ₃ (1000 mg/L)	92.1	82.6	87.4 A
	Control	80.2	74.9	77.5 C
	Mean	86.9	79.7	83.3
	LSD (%5): 3.097			
Panicle length (cm)	KNO ₃ (2000 mg/L)	15.7	16.8	16.2
	KNO ₃ (4000 mg/L)	15.5	17.2	16.4
	GA ₃ (1000 mg/L)	16.2	17.0	16.6
	Control	14.6	16.9	15.8
	Mean	15.5	17.0	16.2
	LSD (%5): 0.615			
Flowering duration (days)	KNO ₃ (2000 mg/L)	88.0	85.0	86.5
	KNO ₃ (4000 mg/L)	87.0	84.0	85.5
	GA ₃ (1000 mg/L)	85.0	83.0	84.0
	Control	83.0	80.0	81.5
	Mean LSD (%5): 0.0	85.7	83.0	84.3
Sterility rate (%)	KNO ₃ (2000 mg/L)	13.5	12.6	13.2 B
	KNO ₃ (4000 mg/L)	11.3	8.2	9.7 C
	GA ₃ (1000 mg/L)	12.6	10.1	11.4 BC
	Control	31.3	31.4	31.3 A
	Mean	17.2	15.6	16.9
	LSD (%5): 2.278			
Germination rate (%)	KNO ₃ (2000 mg/L)	86.6	86.6	86.6 C
	KNO ₃ (4000 mg/L)	87.6	87.6	87.6 B
	GA ₃ (1000 mg/L)	89.6	89.6	89.6 A
	Control	85.6	85.6	85.6 D
	Mean	87.4	87.4	87.4
	LSD (%5): 0.74			

Table V: Effect of seed coating technique on seedling growth of rice at Gönen in 2011

Treatments	Plant height (cm)	Root weight (g plant ⁻¹)	Leaf weight (g plant ⁻¹)	Root + leaf (g plant ⁻¹)
KNO ₃ (2000 mg/L)	16.6	0.031 B	0.071 A	0.101 AB
KNO ₃ (4000 mg/L)	16.7	0.035 A	0.070 A	0.106 A
GA ₃ (1000 mg/L)	17.1	0.037 A	0.073 A	0.109 A
Control	16.1	0.031 B	0.063 B	0.094 B
LSD (%5)	0.633	0.003	0.007	0.009
Repetition	ns	8.010*	ns	ns
Treatments	ns	8.825*	5.176*	7.378*

*Significant at 5% level

On the second year of the trial to determine the effect of the treatments on the early growth stages of the plants, plant height, root dry matter and biomass of the three-week-old seedlings are identified and the effect of treatments was found statistically significant in the parameters root dry matter and biomass (Table V). Root dry matter was found the highest in the treatments 1000 mg/L GA₃ and 4000 mg/L KNO₃. The leaf dry matter values were detected as the lowest in control and the three different treatments showed almost the same performance. On the parameter total biomass, the values of three treatments were higher than control. It was the highest in 1000 mg/L GA₃ (0.109 g plant⁻¹) and 4000 mg/L KNO₃ (0.106 g plant⁻¹) treatments respectively (Table IV). Also Tiwari *et al.* (2011) point out that GA₃ provides the highest biomass for a similar study.

Rice is usually directly sown and grown in flooded paddies so, early, with high ratio and rapid germination of the seeds are desired. On the other hand, for the quality of the seed, high germination performance, vigorous seedling growth and high yield capacity are also important characteristics. It is seen that increase in germination performance, vigorous seedlings and high yield values is due to plant hormones promoted vegetative growth by active cell division, cell enlargement and cell elongation and thus helped in improving growth (Pareek *et al.*, 2000). These findings were in closely agreement with the results of Subbaih and Mittra (1997) and Dunand (1998) who also reported significant increase in plant height, stem elongation and yield in response to gibberellic acid application.

CONCLUSION

Seed coating with 1000 mg/L GA₃ and 4000 mg/L KNO₃; plant growth regulators (PGRs) and various chemicals significantly influence agronomic, morphological

and physiological traits in rice and it was observed that at limited concentrations they stimulate rapid cell division resulting faster vegetation and reproductive growth. Seed coating treatment with GA₃ and other chemicals could be one of the best alternative approaches for rice producers to achieve higher seed yield with maximum economic return.

REFERENCES

- Beşer, N., 2000. *The New Development in Rice Agronomy and Their effects on Paddy Yield and Rice Quality in Turkey During Last Decade*. FAO, The new development in rice agronomy effects on yield and quality in Mediterranean areas. Edirne-Turkey, 13-17, September
- Dunand, R.T., 1993. *Gibberellic Acid Seed Treatment in Rice*. Louisiana State University Agricultural Center, Bulletin No. 842, July 1993, USA
- Dunand, R.T., 1998. Effects of preheading applications of gibberellic acid on rice growth and production. *Proceedings of 27th Rice Tech. Working Group (RTWG'98)*, p: 211. Reno, Nevada, USA
- Elankavi, S., G. Kuppuswamy, V. Vaiyapuri and R. Raman, 2009. Effect of phytohormones on growth and yield of rice. *Oryza*, 46: 310–313
- Farooq, M., A. Wahid, S.M.A. Basra and I.D. Shahzad, 2009. Improving water economy and gas exchange with brassinosteroids in rice under drought stress. *J. Agron. Crop Sci.*, 195: 262–269
- Farooq, M., S.M.A. Basra, A. Wahid, A. Khaliq and N. Kobayashi, 2010. Rice seed invigoration, a review. *Organic Farming, Pest Control and Remediation of Soil Pollutants*, 1: 137–175
- Frankenberger, Jr. W.T. and M. Arshad, 1995. *Phytohormones in Soil: Microbial Production and Function*. Markel Dekker Inc., New York, USA
- IRRI, 1998. *Standard Evaluation System for Rice*. International Rice Research institute, Los Banos, Philippines
- ISTA, 2006. *International Rules of Seed Testing*. International Seed Testing Association (ISTA), 2006 Edition, CH, Switzerland
- Itoh, H., T.M. Ueguchi, N. Sentoku, H. Kitano, M. Matsuoka and M. Kobayashi, 2001. Cloning and functional analysis of two gibberellins 3-hydroxylase genes that are differently expressed during the growth of rice. *Proc. Natl. Acad. Sci.*, 98: 8909–8914
- Kün, E., 1985. *Cereals II*. A.U. Faculty of Agric. Publ. no: 953, Ankara
- Nanda, J.S., 1979. *Rice Breeding Methods*, p: 6. GEU Trainee Prog., Lecture Handout. IRRI Philippines
- Pareek, N.K., N.L. Jat and R.G. Pareek, 2000. Response of coriander (*Coriandrium sativum* L.) to nitrogen and plant growth regulators. *Haryana J. Agron.*, 16: 104–109
- Peng, J., D.E. Richards, N.M. Hartley, G.P. Murphy and K.M. Devos, 1999. Green revolution gene encodes mutant gibberellin response modulators. *Nature*, 400: 256–261
- Richards, D.E., K.E. King, A.T. Ali and N.P. Harberd, 2001. How gibberellin regulates plant growth and development: A molecular genetic analysis of gibberellin signaling. *Plant Physiol. Plant Mol. Biol.*, 52: 67–88
- Scott, J.M., 1989. *Seed Coatings and Treatments and their Effects on Plant Establishment*. Advances in Agronomy 42, Academic Press, Inc. San Diego, California, USA
- Sims, S.L., T.N. Johnston and S.E. Henry, 1968. *Effect of Rates and Timing of N Fertilization on Performance of Rice Varieties*. Agric. Exp. Station, Uni. of Arkansas, Div. of Agric. Ref. Ser. 142
- Steel, R.G.D. and J.H. Torrie, 1980. *Principles and Procedures of Statistics: A Biometrical Approach*. Mc Graw-Hill, New York, USA
- Subbaih, G. and B.N. Mittra, 1997. Effect of foliar spray of micronutrient on growth and yield of rice. *Oryza*, 26: 148–151
- Sun, T., 2004. Gibberellin Signal Transduction in Stem Elongation and Leaf Growth. In: Davies, P.J. (ed.), *Plant Hormones; Biosynthesis, Signal Transduction, Action*, pp: 304–320. Kluwer Academic Publ., Dordrecht, The Netherlands
- Süreç, H., 2002. *Rice Cultivation*. Hasad Publication İstanbul, Turkey
- Tiwari, D.K., P. Pandey, S.P. Giri and J.L. Dwivedi, 2011. Effect of gibberellic acid (GA₃) and other plant growth regulators on hybrid rice seed production. *Asian J. Plant Sci.*, 10: 133–139
- Xu, S. and B. Li, 1988. *Managing Hybrid Rice Seed Production; Proceedings of the 1st International Symposium on Hybrid Rice*, Oct. 6-10, pp: 157–163. International Rice Research Institute, Manila, Philippines
- Zelonka, L., V. Stramkale and M. Vikmane, 2005. Effect and after-effect of barley seed coating with phosphorus on germination, photosynthetic pigments and grain yield. *Acta Univ. Latviensis*, 691: 111–119
- Zeng, D. and Y. Shi, 2008. Preparation and application of a novel environmentally friendly organic seed coating for rice. *American-Eurasian J. Agron.*, 1: 19–25
- Zeng, D., X. Mei and J. Wu, 2010. Effects of an environmentally friendly seed coating agent on combating head smut of corn caused by *Sphacelotheca reiliana* and corn growth. *J. Agric. Biotechnol. Sustain. Dev.*, 2: 108–112
- Zhang, H., Y. Zou, G. Xiao and Y. Xiong, 2007. Effect and Mechanism of Cold Tolerant Seed-Coating Agents on the Cold Tolerance of Early Indica Rice Seedlings. *Agric. Sci. China*, 6: 792–801

(Received 17 January 2012; Accepted 05 April 2012)