Bangladesh J. Bot. **45**(4): 803-810, 2016 (September), Supplementary

EFFECTS OF SEED GRADING ON GROWTH AND YIELD OF SUMMER MAIZE UNDER NO-TILLING PRECISION SOWING CONDITIONS

Xia Zhao[1,2,3], Peipei Mei[4], Fengqi Zhang[2], Fenglan Wu[2], Huazheng Xue[2], Jiajia Zhang[5], Ruidong Huang[3], Baojun Tang[2] and Chaohai Li[1,*]

Cereal Institute, Henan Academy of Agricultural Sciences-450002 Zhengzhou, Henan, PR China

Key words: Summer maize, Seed grading, No-tilling precision sowing, Yield

Abstract

Three summer cultivars of *Zea mays* L., namely Xianyu 335, Zhengdan 958 and Yudan 998 were tested *in vitro* and *in vivo* for their growth and yield under no-tillage and precision sowing. The seeds were selected according to their size and grouped as T1 (>8 mm in dia.), T2 (>7 mm but <8 mm in dia) and T3 (<7 mm dia). Results indicated that the emergence force and emergence percentage of different graded seeds had the same trends, T2 > T1 >T3, among three maize varieties. The bigger the seeds, the greater the plant dry weight; and the sprouting rate, germination rate, sprouting uniformity, plant height uniformity, and grain yield all showed the same trends in that seed grading was better than no grading, and mostly, T1(T2) > T3 > C (no grading seeds), regardless of maize variety. Therefore, this study indicated that the first and second graded seeds were preferable for no-tilling precision sowing in summer maize production. Good graded seeds will be helpful for grain yield increase and resource allocation optimization.

Introduction

Seed grading and selection are necessary steps when trying to improve seed quality (Yan 2001). Demands for higher seed quality are stricter in China. Previous research into several species verified that seed grading could enhance crop yield of inherited consistent varieties (Jiang *et al*. 1996).

The number of grains per wheat head, thousand-grain weight and grain yield all varied with higher yield among different seed grades (Wang *et al*. 1999). Seed size or diameter did not affect crop growth, but mixed (ungraded) seed had significantly lower yields than graded seed (Wang *et al*. 2001). The right selection and grading of seed could effectively increase sowing accuracy, resulted in fast, uniform emergence, strong seedlings, and therefore provided assurances that the variety would achieve its production potential. Precision sowing is a key element to agricultural modernisation. For single particle precision sowing more good quality single seed of different varieties are required (Zhao *et al*. 2012). The present research has therefore been undertaken to carry out laboratory and field experiments with three graded seeds of three types of maize varieties. The aim of the research is to demonstrate the maize growth including seeds germination, sprouts seeding, plant height uniformity, seeding quality and grain yield under no-tillage and precision sowing conditions. It is also aimed at ascertaining the effects of seed grading on the growth and yield of summer maize.

[*]Author for correspondence: <chaohaili2016@126.com>. X. Zhao and P. P. Mei are the Co first authors. [1]College of Agronomy, Henan Agricultural University, 450002 Zhengzhou, Henan, PR China. [2]Cereal Institute, Henan Academy of Agricultural Sciences / Henan Provincial Key Laboratory of Maize Biology, 450002 Zhengzhou, Henan, PR China. [3]College of Agronomy, Shenyang Agricultural University, 110866 Shenyang, Liaoning, PR China. [4]College of Science and Technology, Henan Institute of Science and Technology / Collaborative innovation center of Henan Province in modern biological breeding, 453003 Xinxiang, Henan, PR China. [5]Zhengcun town government of Xin'an County in Luoyang city, 471800 Luoyang, Henann, PR China.

Materials and Methods

Three maize varieties with different seed type character, dent variety Xiangyu 335, semi-dent variety Zhengdan 958, and flint variety Yudan 998 were used, and the detailed properties of the varieties were shown in Table 1. Wind specific gravity screening separation was used to separate the seeds. According to seed size, each variety was divided into three graded sets of seeds: T1 (>8 mm in dia.), T2 (>7 mm but <8 mm in dia) and T3 (<7 mm dia). In addition, mixed seed was used as a control (C, only passed wind specific gravity screening separation).

Table 1. The properties of the three maize varieties.

Variety	Crude protein (%)	Crude fat (%)	Crude starch (%)	Lysin (%)
Xiangyu 335	9.55	4.08	74.16	0.30
Zhengdan 958	9.33	3.98	73.02	0.25
Yudan 998	11.27	4.00	70.25	0.29

The laboratory tests were conducted at the Key Laboratory of Maize and Cereal Biology, Henan Academy of Agricultural Sciences, in April, 2012 and April, 2013. One thousand seeds were randomly selected from each individual variety of different graded seeds and weighed. Seed germination test was performed after National Seed Inspection Procedure in China (GB 4404.1, 2008). Seed emergence force (EF = (number of germinated seeds at 4 days after sowing/total number of tested seeds) × 100) and emergence percentage (EP = (number of germinated seeds at 7 days after sowing/total number of tested seeds) × 100), respectively were recorded at 4 and 7 days after sowing. Meanwhile, 20 typical seedlings were selected for measuring the seedling dry weight. The average weight (two measurements) was used to compare varieties of different graded seeds.

Table 2. Background properties of soil (0 - 20 cm depth).

Experimental field	Organic matter (%)	Hydrolyze N (mg/kg)	Available P (mg/kg)	Available K (mg/kg)
YF	1.44	56.80	21.90	173.50
PA	1.10	88.20	6.40	221.40

During the growing season for summer maize in 2012 and 2013, field trials were carried out at Henan Modern Agricultural Research station (YF) and Henan Pingan Seed Company trial site (PA), respectively. The two experimental fields are on an alluvial-soil, on level terrain, with controllable drainage or irrigation conditions, and uniform soil fertility (Table 2).

Field experiments were designed using a randomised block design with four replicates. The treatments were the three maize cultivars and four corresponding seed gradings which were the same as those used in laboratory tests. The plant density was 67,500 plants per ha. There were six rows in each plot. The layout gave a plot measuring 3.6 × 6 m. At the two experimental fields, no-tillage, precision sowing machinery was used on 10 June for maize sowing, and the depth of seed sowing was 5 cm. The harvest dates were both on 9 October (both sites, on both years). The machinery used for sowing was a 2BQ-4 (Shijiazhuang Agricultural Machinery Sales Company of Chinam, Shijiazhuang, China). After sowing, the fields were irrigated, and all plots were treated with compound fertiliser at a rate of 750 kg/ha (N : P : K = 15 : 15 : 15); other field management techniques were the same as those used in local maize fields.

Measurements of sprouting and germination were followed after Gan *et al*. (2000). In detail, 4 days after sowing, the number of sprouting seed was recorded everyday, until 7 days. The sprouting rate (SR% = Number of sprouting seeds/total number of sown seeds × 100%) and Germination rate (GR% = 1/number of days at stable sprouting rate × 100%) were calculated.

Ten plants per plot were randomly selected for measuring: Plant height, plant dry weight, and leaf area when the plants reached their 3rd and 6th leaf stage, respectively (Yang *et al*. 2009). Using the following formula, sprouting uniformity at the 3rd leaf period and plant height uniformity at the 6th leaf period were, respectively calculated.

$$\text{Sprouting / plant height uniformity degree} = \frac{\overline{X}}{\sqrt{\dfrac{\sum X^2 - \dfrac{(\sum X)^2}{X}}{N-1}}}$$

where, X is sprouting rate or plant height, $\overline{X}$ is the average sprouting rate or plant height, N is the total number of seeds used for measuring sprout rate and plant height.

Samples collected by harvesting two rows in the middle of each plot out with the first 0.2 m of each row were used to determine the grain yield.

Statistical significance of differences between treatments was analysed by DPS7.05.

Results and Discussion

Test results indicated that the seed grading made in terms of 1000-seed weight, seed size, emergence force, emergence percentage, and seedling dry weight all showed significant differences (Figs 1 and 2). On the whole, bigger seeds with larger seed sizes usually showed heavier 1000-seed weights and seeding dry weight, regardless of maize variety used.

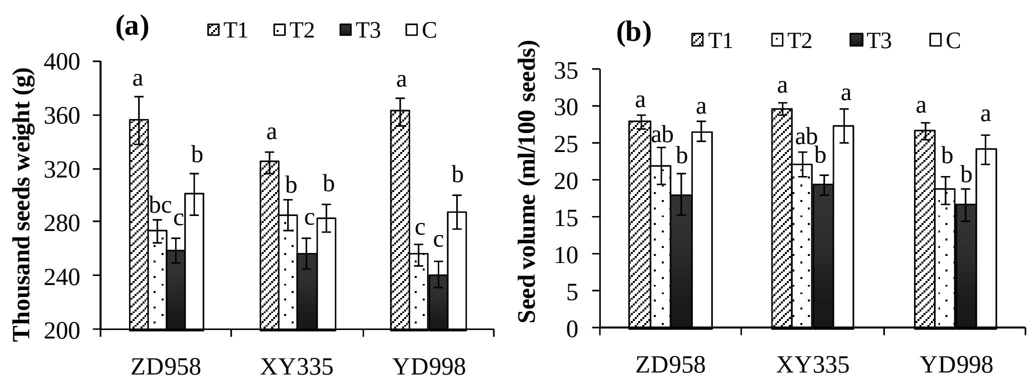

Fig. 1. Thousand-seed weight and seed volume of different graded seeds (Values are means of 3 replicates). Values followed by the same letters are not significantly different between graded seeds of one maize variety ($p > 0.05$), according to DMRT).

For dent variety Xianyu 335, the significant differences of thousand seeds weight were found among T1, T2, T3 and C, except for the difference between T2 and C, there 26.19% increase in T1 was observed in comparison to that of T3. For semi-dent variety Zhengdan 958, there was significantly different from those of T2, T3, and C. For flint variety Yudan 998, the T1 1000-seed weight was significant when compared with that of T2, T3 and C, there 50.15% heavier than T3.

The trends in emergence force and percentage for the three seed type varieties of different gradings of seeds were the same: T2 > C > T1 > T3. This indicated that seed size affected the seed germination, and the best seed size had to be chosen for maximum plant yield. The emergence force and percentage of T1 and C significantly differed from those of T2 and T3, respectively.

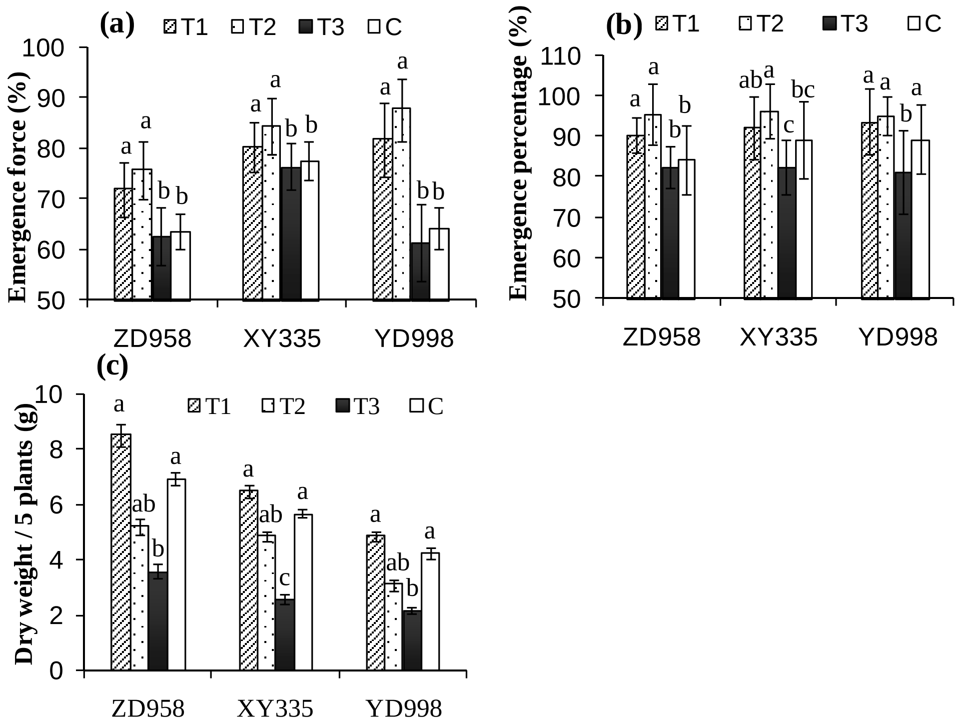

Fig. 2. The germination characteristics of different graded seeds.

Respective of seed varieties, seedling dry weight was, in descending order: Dent variety > semi-dent variety > flint variety.

Field experimental results indicated that the sprouting rate for the three varieties of different graded seeds had consistent trends (Fig. 3), showing that T2 > T1 > T3 > C, while the differences in seed grading were insignificant. For Zhengdan 958, the average sprouting rates of T2, T1, and T3 in two experiments increased, respectively by 4.26, 3.69 and 2.82% compared to Zhengdan 958 C. These indicated that the sprouting rate of each variety of graded seed was higher than those with ungraded seeds.

Germination rates among three varieties of different graded seeds differed (Fig. 3). The trend was similar to the sprouting rate, in that: T2 > T1 > T3 > C, there they all significantly differed from that of C. For Zhengdan 958, T2, T1, and T3, the average germination rate in two experiments, respectively improved by 20.26, 30.26 and 15.84% compared to C. Similar trends in Xianyu 335 and Yudan 998 were shown. Graded seed therefore had a higher germination rate, and sprouted earlier than ungraded seed.

Fig. 4 shows that the trend in extent of sprouting uniformity among different graded seeds for each variety was similar to that in the extent of plant height uniformity, i.e., T2 > T1 > T3 > C. The differences between T2 and T1, and T3 and C, were insignificant, but both T2 and T1 differed significantly from T3 and C, respectively.

In two field experiments, the average sprouting uniformities of T2, T1 and T3 of Zhengdan 958, were 5.63, 5.30, and 5.27, which respectively increased by 9.78, 3.41 and 2.73%, compared to C. Their plant height uniformities were 5.46, 5.34 and 5.18, which were improved by 8.02, 5.74 and 2.57%, compared to Zhengdan 958 C. There were the similar trends in Xianyu 335 and Yudan 998. This suggested that the sprouting uniformity and plant height uniformity of the larger sized gradings of each variety were all significantly superior to ungraded seed.

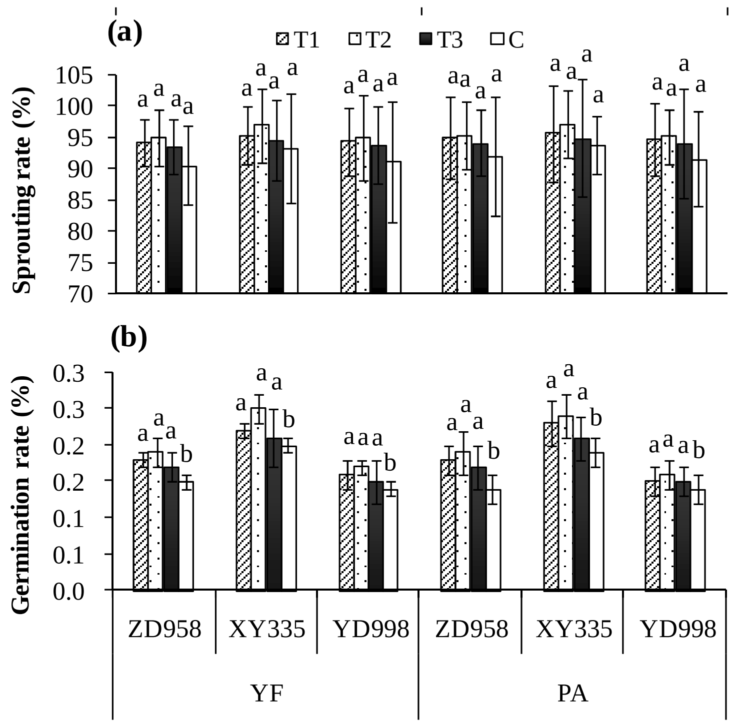

Fig. 3. Sprout rate and germination rate of different graded seeds.

The seedling quality during the 6th leaf spreading period is shown in Fig. 5. The plant height and leaf area were not significantly different among the three varieties, while the plant dry matter among different graded seeds differed, showing the trend: T1 > T2 > C > T3. The average plant dry matter of Zhengdan 958, T1 and T2 were 18.82 and 15.96 g, respectively increasing by 28.68 and 9.09% over Zhengdan 958 C; but T3 dry matter mass was 13.48 g: A decrease of 8.53%. The trend of the other two varieties in plant dry matter was both similar to Zhengdan 958.

The grain yield among different graded seeds of each variety was significantly different (Fig. 6). The yield trend of different graded seeds under no-tillage and precision sowing condition was: T2 > T1 > C > T1. For Zhengdan 958, the T1 yield was significantly different from those with T2 or T3. Compared to Zhengdan 958 C in two experiments (YF, PA), the yield of T2 was increased by 11.25 and 12.87%, respectively. For Xianyu 335, the T1 yield presented significant differences with T3 and C, but not with T2. In the YF and PA fields, Xianyu 335 T2 was improved by 9.52 and 7.74%, respectively, compared to that of C. For Yudan 998, the T2 yield was improved by 11.67%, while T3 decreased by 1.34% compared to that of C.

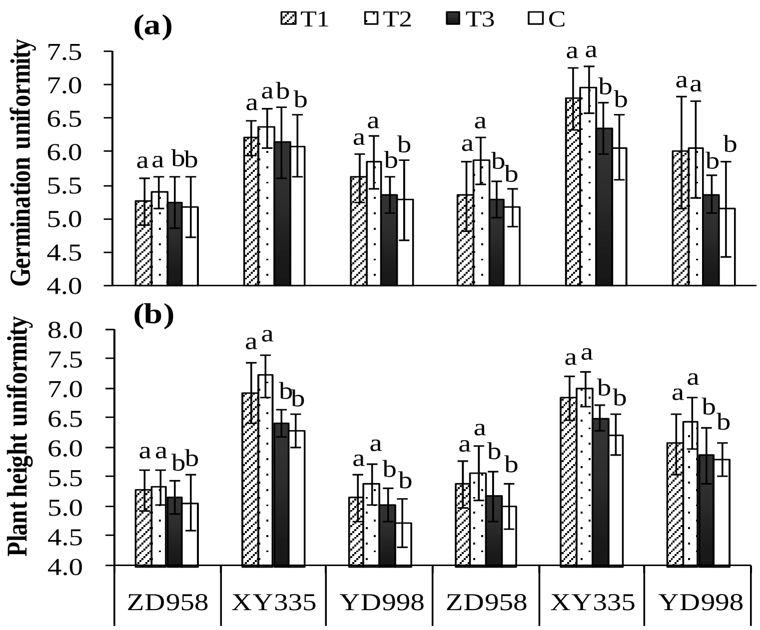

Fig. 4. Germination / plant height uniformity degree of different graded seeds.

Smaller seeds have a surface/volume ratio higher than larger seeds. This does not necessarily mean that lots composed of many small seeds are physiologically superior to larger seeds. Given the normal variation in seed size that comprises seed lots regardless of species, the question remains - which size class generally has seeds with superior physiological potential? For this question, the authors carried out the agronomic research on single seed of 3 maize varieties through agricultural production, and last for precision sowing production. And the authors have generally established that “large” seeds usually have better performance with respect to germination and seeding quality, and plant yield. The study indicated that the emergence force and emergence percentage of different graded seeds had the same trends, T2 > T1 >T3, among three maize varieties. The bigger the seeds, the greater the plant dry weight; and the sprouting rate, germination rate, sprouting uniformity, plant height uniformity, and grain yield all showed the same trends in that seed grading was better than no grading, and mostly, T1(T2) > T3 > CK (no grading seeds), regardless of maize variety. So the authors suggest that T1 or T2 graded seed should be used in no-tillage, mechanised and precision sowing conditions.

Several studies have shown that this is not always a general rule since seeds considered “large” for a cultivar or in a given crop year may be “medium” or “small” in other years (McDonald 1999, Idowu and Owolarafe 2014). In contrast, seeds greater than 8 mm, larger than medium size, also showed low performance because they were prone to mechanical injury and impact damage during harvest and processing as a result of their larger size.

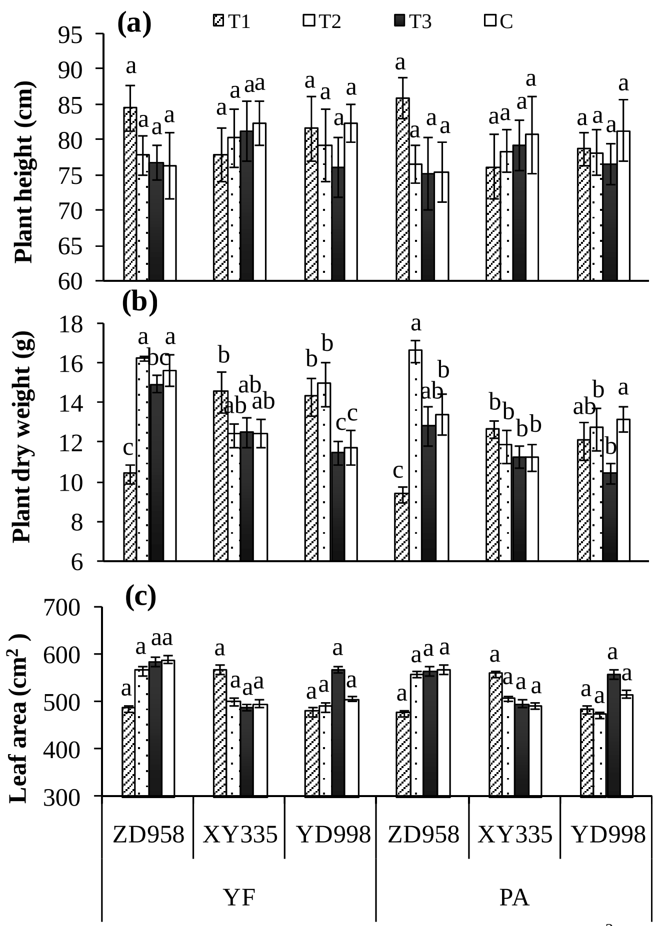

Fig. 5. Plant height (cm), plant dry matter weight (g) and leaf area (cm^2) of different graded seeds during the sixth leaf spreading period.

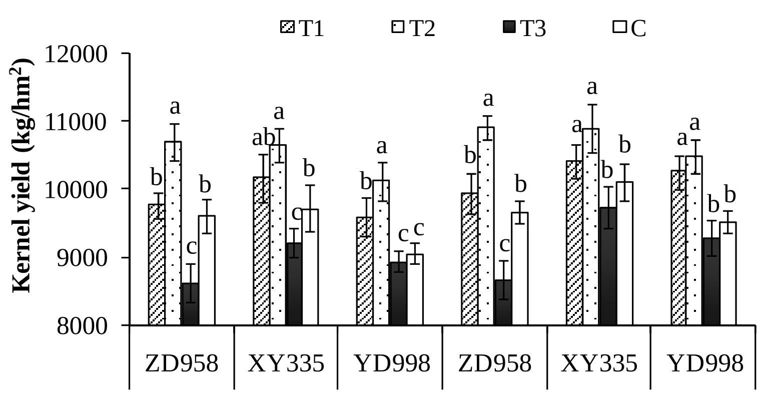

Fig. 6. The kernel yield (kg/hm^2) of different graded seeds.

Precision sowing is a trend in modern maize development. Seed quality is the basis of precision sowing of maize. In maize production, whether the seeding is uniform or not affects kernel yield. So improving the uniformity of seeding could increase maize yield (Bian *et al*. 2008, Zhang 2005). However, the difference in germination rates of different seeds, or seed sizes, were important reasons influencing seeding uniformity (Zhang and Maun 1990). During seed processing and production, seed grading was a key step in ensuring seed size uniformity, and is a condition for ensuring maize population uniformity in the field (Chen *et al*. 2010, Idowu and Owolarafe 2014).

Acknowledgements

The authors express their thanks to anonymous reviewers for comments and suggestions that improved the manuscript. This research was funded by two Project Grants from The Maize Industry Technology System of Henan Province (S2010-02-04 and S2015-02-04) and a grant from the Research Projects of Agricultural Public Welfare Industry in China (201503130).

References

Bian SF, Zhao HX. Meng XM, Fang XQ, Tan GB, Zhang LH, Yang FT and Yan WP 2008. Study on the relationship between the ear characteris tic uniformity and yield of super high- yielding corn. J. Maize Sci. **16**(4): 119-122.

Chen HJ, Feng ZQ and Sun WH 2010. The study of seed processing technology and equipment Allocation on corn. China Seed Industry **11**: 22-24.

Gan L, Ju PH and Leng HY 2000. The seed selection classification and precision seeding of Soybean. Reas. Agric Modern **2**: 124-125.

Idowu DO and Owolarafe OK 2014. Physical properties of snake gourd seed (*Trhichosantes cucumerina* L.) relevant in grading and separation. Agricultural Engineering International: CIGR Journal **16**(1): 303-312.

Jiang JM, Yu MK, Hu SC, Luo XZ, Tang JD and Cao ZR 1996. Effect of seed sorting on germination and seeding quality of Slash pine. Sci. Silv. Sin. **9**(3): 290-295.

McDonald MB 1999. Seed deterioration: Physiology, repair and assessment. Seed Sci. Technol. **27**: 177-237.

Wang XG, Cai Y and Yu RJ 1999. Effect of seed graded and series of processing sowing in wheat. Seeds of the world in China **4**: 17.

Wang YW, Li NC, Meng QX, Yin YS and Sun XJ 2001. Effect of soybean cultivation with seed cleaning and grading. Heilongjiang Agric. Sci. **3**: 47-49.

Yan QC 2001. Spermology. China Agri. Press, Beijing. pp. 28-156.

Yang CS, Zhao X, Li CH, Liu TX and Liu JB 2009. Effect of stubble treatment on machine sowing quality and early growth on summer corn. J. Henan Agric. Sci. **1**: 25-28.

Zhao X, Wang XX, Huang RD, Li CH and Tang BJ 2012. Differences of the quality of precision planting seeds in maize. J. Maize Sci. **20**(4): 95-100.

Zhang HY 2005. The study progress of the regularity degree of crop agronomic traits. J. Hunan Agric. Sci. **4**: 33-36.

Zhang J and Maun M 1990. Sand burial effects on seed germination, seedling emergence and establishment of *Panicum virgatum*. Holarctic Ecol. **13**: 56-61.

(Manuscript received on 11 May, 2016; revised on 4 July, 2016)