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Full Length Research Paper

Analysis on yield components of elite maize variety Xundan 20 with super high yield potential

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Xundan 20 was released by Hebi Academy of Agricultural Sciences in 2003. The stability, adaptation and yield components of Xundan 20 were analyzed using data from Huanghuaihai national tests in 2001 and 2002 and from high yield trials from 2005 to 2010. The results showed that variety Xundan 20 yielded most and increased significantly than Nongda 108 (Control, CK) in Huanghuaihai national tests in 2001 and 2002. The yield potential of variety Xundan 20 was so high that it created a series of new record in China. The yield of variety Xundan 20 of 15971.7 kg/ha created the highest record of summer maize in China in 2007, with the yield components of 77835 plant/ha, 205.2 g/ear, 596.16 grains/ear and 350 g per 1000-grain. The variation coefficient of variety Xundan 20 was small and its yield was stable. It is based on excellent comprehensive resistance of variety Xundan 20 to main disasters in Huanghuaihai region such as diseases, pests and lodging.

Key words: Maize, Xundan 20, stability, wide adaptability, yield components, super high-yield.

INTRODUCTION

Maize is a C4 crop and its yield potential is higher than C3 crops such as wheat and rice. The yield of maize in China was about 4250 kg/ha. Although the planting area of maize is the largest in all crops, its productivity cannot fit the requirement of animal husbandry and starch processing industry. According to prediction of Zhang et al. (2009), the gap between requirement and productivity of maize would be 5.1×10^{10} kg by 2020. So, to improve the productivity of maize, it is the most important requirement for Chinese maize industry. The total production of maize may be enhanced by a variety of ways such as planting area expansion, soil improvement, fertilization and tillage optimization. However, the most effective and direct way is to breed varieties with high yield and wide adaptability (Golbashy et al., 2010). Studies have proved that 52.9% of maize yield increment was attributed to varieties, and the rate of improvement was 89.1 kg/ ha per year (Ci et al., 2010; Li and Wang, 2009).

Xundan 20 (Xun97-1) was released by Hebi Academy of Agricultural Sciences in 2003. It was approved by nation, Hennan and Hebei Provinces in 2003, by Hunan Province and Inner Mongolia autonomous region in 2006, and by Tianjin in 2009 (Qin et al., 2011).

From 2005 to 2010, variety Xundan 20 continuously created a series of yield records of summer maize in China and world. In 2007, variety Xundan20 created a Chinese and world yield record of 15971.7 kg/ha in 1 ha area (Qin et al., 2011). It was considered as one of nation's main maize varieties by Ministry of Agriculture of China since 2004 and the planting area increased quickly and reached to 3.24×10^6 ha in 2010 (Qin et al., 2011). Now it is the maize variety with the biggest plantation area in Henan Province and Huanghuaihai region. The objective of this paper was to analyze the yield component and stability of Xundan 20 and provide the reference to breed maize varieties with high yield and wide adaptability.

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Abbreviations: HSC, High-stably yielding coefficient; **CV,** coefficient of variation.

MATERIALS AND METHODS

Variety Xundan 20 is the main material in this paper. The maize variety Pu 9794, LD661, HD9912, Zhengdan 518, 2735 and the control variety Nongda 108 were also selected to analyze the adaptibility and stability of Xundan 20.

Experimental design

National Huanghuaihai region tests were conducted in 2001 and 2002 with variety Nongda 108 as control. There were 24 plots in 2001, including seven in Henan Province (Sui county, Puyang, Nanyang, Mengjin, Luohe, Crop institute of Henan academy of agricultural sciences, Baofeng), 4 in Shangdong (Zaozhuang, Yantai, Dezhou, Changqing), 5 in Hebei (Crop institute of Heei academy of agricultural sciences, Zunhua, Wen’an, Handan, Anguo), 2 in Anhui (Suzhou, Jieshou) and Jiangsu(Huaian, Dongxin), 1 in Shanxi (Yuncheng) and 3 in Shanxi (Xianyang, Jingyang, Dali). There were 23 plots in 2002, including 6 in Henan Province (Baofeng, Luoyang, Nanyang, Puyang, Sui county, Zhumadian), 5 in Shangdong (Changqing, Dezhou, Liaocheng, Yantai, Zaozhuang), 4 in Hebei (Anguo, Gaocheng, Handan, Ningji), 2 in Anhui (Su county, Jieshou) and Jiangsu (Huaian, Lianyungang), one in Shanxi (Yuncheng) and 3 in Shanxi (Xianyang, Jingyang, Dali). Experiments were arranged in a randomized block design with three replications. Each plot area was 20 m^2 consisted of 5 rows and the central 3 rows (12 m^2) harvested to evaluate yield and yield components. The experiments were managed conventionally.

The data for stability and lodging analysis derived from National Huanghuaihai Region tests in 2001 and 2002. The resistance to disease and pest was analyzed according to the appraisal result by Plant Protection Institute Hebi Academy of Agricultural Sciences. The rates of lodging and stalk rots were recorded, and other disease and pest incidences were rated on a scale of 1(excellent) - 9(very poor) as described by Yin et al. (2010). The 154 data for yield component of variety Xundan 20 were derived from National Huanghuaihai Region Tests, production test in 2001/2002 and the high-yield research and demonstration trials in Xunxian County from 2005 to 2010.

Statistical analysis

Data collected were subjected to analysis by coefficient of variation (CV) and High-stably Yielding Coefficient (HSC) (Wen and Liang, 1994). With average yield (X) of variety in multi-environment trails, as its yield phenotype value and its standard deviation(S) as environment variance, genetic value of variety would be the part of (X-S). The variety with yield stability higher than 10% CK, was used as target variety.

$$HSC_i=((1.10X_{CK}-S_{CK})-(X_i-S_i))/(1.10X_{CK}-S_{CK})\times 100\% \quad (1)$$

Where: HSC_i = High-stably yield coefficient of i-th variety, the smaller HSC, the better yield and stability of variety; X_{CK}= average yield of CK in multi-environment trails; S_{CK}= standard deviation of CK; X_i= average yield of i-th variety in multi-environment trails, S_i= standard deviation of i-th variety.

In the premise of keeping stable yield and permutation order of target variety, Formula (1) could be simplified as following through removing S_{CK}:

$$HSC_i=(1.10X_{CK}-(X_i-S_i))/1.10X_{CK}\times 100\%=1-(X_i-S_i)/1.10X_{CK}\times 100\% \quad (2)$$

For ease of calculation, Formula (2) could be further simplified:

$$HSC_i=(X_i-S_i)/1.10X_{CK}\times 100\% \quad (3)$$

Different from Formulae (1) and (2), the variety with bigger HSC was more yielding and stable in Formula (3).

RESULTS AND DISSCUSION

Growth and yield component

In 2001, except Nongda 108 (Control, CK), the growth period of XD20 was shorter than all the other tested hybrids. While in 2002, among all the tested hybrids, the growth period of XD20 was the shortest with 4.64 days shorter than CK. (Table 1). The varying growth period may be attributed to the fluctuation of weather pattern such as temperature, available soil moisture (Olaoye, 2009; Sanari et al., 2010). It is generally recognized that longer maturity variety produced greater yield (Agele, 2006). Analyzed across the two growing seasons, variety Xundan 20 matured earlier than other varieties. Variety Xundan 20 conquered contradiction between maturity and yield. The maize maturity in Huanghuaihai region was limited by the harvesting and planting time of wheat. The fully matured wheat is needed for mechanical harvesting, and it delayed the planting time of maize and decreased the maize maturity. The variety with short maturity and high yield was required for producer. The Xundan 20 was therefore found to meet the production requirement.

Lower plant and ear height augments plant lodging resistance of varieties (Esechie et al., 2004). Results showed that plant height of Xundan 20 was lower than other varieties except Nongda108 and HD9912 in 2001 and 2002, respectively. The ear length of Xundan 20 was inferior to other varieties in 2001 and 2002; however, the ratio of bald length to ear length was the smallest attributing mainly to the least bald. It proved that Xundan 20 was excellent in fecundity which was benefitial for variety adaptability (Meng et al., 2007). Grain weight per ear is an important yield component for maize production. The grain weight per ear of Xundan 20 was the second biggest in 2001 and 2002, and was 11.24 and 8.1 g higher than Nongda 108, respectively. It is interesting for variety Xundan 20 with the shortest ear but second heaviest ear. As far as 1000-grain weight is concerned, variety Xundan 20 was 27.21 and 21.92 g higher than CK in 2001 and 2002, respectively.

Resistance analysis

The incidence of diseases, pests and lodging was comparatively less in 2001 than in 2002 (Table 2). In 2001, except Northern leaf blight, the average incidence of Xundan 20’ other 5 diseases, including Stalk rots,

Table 1. Agronomic traits of varieties including Xundan 20 in national regional tests (2001-2002).

Year/cultivar	Maturity (d)	Plant height (cm)	Ear height (cm)	Ear length (cm)	Bald length (cm)	Grain weight per ear(g)	1000-Grain weight(g)
2001							
Xundan20	96.63±0.96	243.67±3.69	106.21±2.61	16.78±0.31	0.24±0.08	176.45±6.48	324.75±8.38
Pu 9794	97.13±1.03	303.92±5.68	137.42±3.31	19.34±0.35	0.89±0.18	171.57±6.15	317.71±7.63
LD661	96.08±0.82	289.75±5.33	117.88±2.88	19.52±0.37	1.20±0.20	172.64±6.37	322.63±9.95
HD9912	96.25±0.81	264.50±3.98	112.08±2.75	18.80±0.32	1.42±0.18	177.59±6.87	345.92±7.94
Zhengdan518	97.13±1.00	271.75±3.87	128.79±3.10	17.40±0.34	0.76±1.75	174.06±5.85	347.71±7.60
2735	97.75±0.95	270.04±4.09	114.99±5.17	17.49±0.31	0.48±0.15	172.61±5.71	292.13±6.62
Nongda108	99.50±0.90	253.71±3.48	106.42±2.56	19.30±0.32	1.35±0.17	165.21±5.56	297.54±6.71
2002							
Xundan20	95.59±1.07	241.17±3.25	106.30±2.94	16.70±0.22	0.34±0.47	164.61±8.18	314.40±6.28
Pu 9794	96.14±1.13	290.70±3.75	134.96±2.78	18.65±0.38	1.30±0.23	158.62±6.05	313.09±6.40
LD661	96.64±1.04	282.04±4.19	115.02±5.66	19.37±0.30	1.20±0.24	161.09±6.54	312.64±6.80
HD9912	96.95±1.01	241.35±2.88	99.91±1.86	18.99±0.30	2.09±0.32	168.44±6.90	339.30±6.04
Zhengdan518	97.23±1.05	268.22±3.43	128.26±2.13	17.13±0.27	1.00±0.22	163.16±5.63	338.26±6.59
2735	98.00±1.02	270.22±2.96	116.91±2.80	17.36±0.33	0.73±0.25	157.23±6.97	290. 32±7.39
Nongda108	100.23±0.98	253.78±4.07	108.26±2.95	19.38±0.34	1.32±0.22	156.51±5.34	292.48±6.74

Table 2. Resistance analysis of varieties including Xundan 20 in national regional tests (2001-2002).

Year/cultivar	Northern leaf blight	Southern leaf blight	Stalk rots (%)	common smut	Dwarf mosaic virus disease	Asian corn borer	Curvularia leaf spot	Lodging rate (%)
2001								
Xundan20	5	1	0	0	0	3	5	2.80
Pu 9794	1	5	0	0	3	3	5	4.38
LD661	1	1	0	0	0	3	3	4.95
HD9912	3	1	0	0	3	3	3	7.17
Zhengdan518	1	5	0	0	7	3	5	4.26
2735	1	1	23.2	0	0	3	3	3.30
2002								
Xundan20	7	3	27.3	7	0	3	3	3.88
Pu 9794	5	5	58.3	0	9	3	5	7.15
LD661	7	1	41.7	0	0	3	5	7.99
HD9912	7	3	45.5	0	0	1	5	7.46

Table 2. Contd.

Zhengdan518	7	5	8.3	0	50	7	7	10.26
2735	7	3	28.6	0	42	3	5	3.68

Table 3. Yield stability analysis of variety including Xundan20 in national regional tests (2001-2002).

Year/cultivar	Yield (kg/ha)								CV (%)	HSC (%)	Increasing yield plots
	Anhui	Hebei	Henan	Jiangsu	Shandong	Shanxi	Shanxi	Mean			
2001											
Xundan20	9118.50	10356.90	9288.60	7766.25	11425.20	8745.00	7204.95	9129.30	17.88	82.31	21
Pu 9794	9145.50	9425.70	9211.35	6471.75	9962.25	7633.50	7623.45	8496.15	18.47	75.84	17
LD661	8490.75	9268.80	9065.85	8249.25	11347.50	6022.50	6739.50	8454.90	20.45	73.27	19
HD9912	8675.25	9243.90	9144.90	7335.00	10299.75	6997.50	7067.55	8394.75	18.20	75.11	16
Zhengdan518	8741.25	10084.50	9294.60	6404.25	10360.50	8250.00	7563.00	8671.20	17.99	77.83	19
2735	9971.25	10047.30	9556.05	6254.25	10952.70	7539.00	7588.95	8844.15	19.75	77.47	21
Nongda108	8559.75	9116.10	8441.40	7266.00	10082.70	7278.00	6780.00	8217.75	17.29	74.63	
2002											
Xundan20	9053.25	9072.75	8269.80	8346.75	10079.70	8008.50	8825.55	8938.80	13.72	85.26	21
Pu 9794	8668.50	6187.50	8071.05	8460.00	8966.40	5964.00	8401.50	7975.35	19.22	71.23	11
LD661	8814.75	6384.45	8097.30	8507.25	9767.70	7230.00	8076.45	8220.45	20.73	72.04	9
HD9912	8652.75	7237.50	7808.25	7533.75	9619.50	7855.50	8726.55	8274.15	17.78	75.21	14
Zhengdan518	8336.25	8056.20	8157.30	7922.25	9771.00	7389.00	8695.50	8522.55	15.54	79.58	12
2735	8687.25	7587.75	8002.20	7895.25	9991.80	7098.00	9234.45	8534.40	17.87	77.49	14
Nongda108	8349.75	8067.00	7851.30	8163.75	9525.30	7716.00	7890.45	8322.45	14.38	78.77	

Common smut, Dwarf mosaic virus disease, Asian corn borer and Curvularia leaf spot, was equal to or lower than the other varieties. In 2002, except Common smut, the average incidence of Xundan 20' and other 5 diseases was equal to or lower than other varieties'. The lowest lodging incidence of Xundan 20 could be attributed to low plant and ear height (Table 1). Analyzed across the two growing seasons, variety Xundan 20 was outstanding in conferring resistance to diseases, pests and lodging. Salasya et al. (2007) has found that resistance of a given variety influenced its adoption by the producer. Excellent resistance may be one of the reasons for the largest planting area of Xundan 20 in Huanghuaihai region.

Yield stability analysis

The yields of Xundan 20 were higher than other cultivars in both 2001 and 2002 (Table 3). It was outstanding in Hebei, Jiangsu, Shandong and Shanxi in 2001 and in Anhui, Hebei, Henan, Shandong, Shanxi in 2002 with mean yield superior to other varieties. Variety Xundan 20 out-yielded variety Nongda 108(CK) by 10.95 and 7.41% in 2001 and 2002, respectively. The coefficient of variation reflected the static stability of the cultivar. The lesser the coefficient of variation; the better is the static stability of cultivar,

Table 4. Yield component analysis of Xundan 20 with different yields.

Parameter	Yield (kg/ha)					Mean
	<7500	7500～9000	9000～10500	10500～12000	12000<	
Plots	7	40	52	37	18	
Yield (kg/ha)	6335.25±284.21	8448.61±71.69	9609.61±51.85	11174.04±85.95	13791.09±271.25	9881.10
Density (plant/ha)	52596.17±1876.17	56169.31±909.41	58776.38±874.51	60171.58±1444.50	72797.42±2142.67	59745.30
Single ear weight (g)	120.74±4.85	151.96±2.75	165.15±2.34	187.82±4.85	191.49±5.12	165.80
Grains number per ear	451.88±20.00	500.25±9.50	526.65±6.84	570.14±8.72	578.58±13.78	530.77
1000-grain weight(g)	277.00±16.83	301.39±3.87	311.21±3.43	347.67±6.89	361.12±5.30	319.89

and the less varied is the cultivar to the environments. However, the better is the stability of the variety; the more unfavorable is it, to improve yields by methods of cultivation (Song et al., 2010). The HSC is a parameter for yield and stability, which was significantly positive with yield and negative with CV and standard deviation (Zhang et al., 2003). The bigger HSC, the better yield and stability. The yield of Xundan 20 was the highest in 2001, and its CV was 17.88% higher only than Nongda108, but its HSC was the highest. The yield of Xundan 20 was the highest in 2002, and its CV of 13.72% was the least, while the HSC was the highest.

Variety Xundan 20 yielded higher than CK in 21 plots in National Huanghuaihai Maize Region Tests (87.5% in 2001 and 91.30% in 2002). It was obviously higher than the other varieties. For example, 2735 provided by Beijing office, American Monsanto Co. also was higher than CK in 21(87.5%) plots, however, only 60.87% plots increased in 2002. It also showed variety that Xundan 20 was more stable and productive, and was consistent with the results by CV and HSC.

Yield component

The result (Table 4) showed that the mean yield of Xundan 20 was 9881.10 kg/ha, with plant density 59745.30 plants/ha, grain weight per ear 165.80 g, 530.77 grains per ear and 1000-grain weight 319.89 g. The record yield of Xundan 20 was 15971.7 kg/ha in Xun County agronomy institute with 1 ha measured by national maize specialists in 2007. And its yield components were a plant density of 77835 plants/ha, grains weight per ear of 205.2 g and grain number per ear of 596.16 grains and 1000-grain weight of 350 g. Analysis on yield components of variety Xundan 20 from 154 plots (times) revealed that, the yields of Xundan 20 in 7 plots (times) were lower than 7500 kg/ha, 129 plots (times) between 7500 to 12000 kg/ha and 18 plots (times) more than 12000 kg/ha, which accounted for 4.55, 83.77 and 11.69% of total plots (times), respectively. The yield, grains weight per ear, and plant density, grain number per ear and 1000-grain weight increased by 117.69, 58.60, 38.42, 28.04 and 30.37%, respectively, with the yield increased from below 7500 kg/ha to above 12000 kg/ha. Yield component attributed differently to grain yield.

For example (Table 4), when grain yield increased from 9000-10500 kg/ha to 10500-12000 kg/ha, the increment of grains number per ear, 1000-grain weight and grain weight per ear increased more than plant density. However, plant density increased 20.99% from 10500 to 12000 kg/ha, to more than 12000kg/ha, while the increment of grains number per ear, 1000-grain weight and grain weight per ear decreased. The yield, grain weight per ear, and plant density, grain number per ear and 1000-grain weight increased by 117.69, 58.60, 38.42, 28.04 and 30.37% respectively, with the yield increased from below 7500 kg/ha to above 12000 kg/ha. The increment of grain weight per ear was the highest, and it was the result of grain number per ear and 1000-grain weight with the similar increasing rate.

Thereafter, the yield could be increased largely by improving plant density steadily, and increasing grain weight per ear from grains number per ear and 1000-grain weight meantime. However, account for the different contribution of yield component to yield, the yield increase could be realized by improving the factor with biggest contribution to yield firstly, and drive other factors.

Conclusion

The result obtained revealed that the mechanisms of the elite maize variety Xundan 20 are as follows: firstly, the basic yield stability of Xundan20 is that Xundan 20 is compressively resistant to the main disease, pests and their lodging; secondly, the high production efficiency and yield of Xundan

20 with a shorter growth period is more suitable for the cropping system in the growing region; and thirdly, Xundan 20 has a relatively higher yield under different fertilizer levels by adjusting its yield components to the best state.

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