Available online www.jocpr.com

Journal of Chemical and Pharmaceutical Research, 2014, 6(7):1124-1129

Research Article

ISSN : 0975-7384
CODEN(USA) : JCPRC5

Effects of formulated fertilizer, irrigation and varieties on wheat yield in Shaanxi China

Xiaoying Wang[1], Yanan Tong[1,2*], Pengcheng Gao[1], Fen Liu[1], Yimin Gao[1], Zuoping Zhao[1] and Yan Pang[1]

[1]College of Resources and Environment, Northwest A&F University, Yangling, Shaanxi, China
[2]Key Laboratory of Plant Nutrition and Agricultural Environment in Northwest, Ministry of Agriculture, Yangling, Shaanxi, China

---

ABSTRACT

In order to study the effects of formulated fertilization, irrigation and different varieties on crop yields and farmer's income, this research used household survey data and demonstration test data of formulated fertilization, which was collected from the project of soil testing and formulated fertilization in Shaanxi province from 2007 to 2011. For analysis, there were a total of 53 counties in the sample. The results show that in Weibei, Guanzhong and Qin-Ba regions, compared with conventional fertilization, formulated fertilization decreased nitrogen (N) fertilizer rates by 31.92%, 12.59% and 10.13% respectively, decreased phosphate (P_2O_5) fertilizer rates by 20.44%, 2.10% and 26.19% respectively, increased potassium (K_2O) fertilizer rates by 105.98%, 193.99% and 382.58% respectively. The yields of wheat improved 330 kg ha^{-1}, 403 kg ha^{-1} and 738 kg ha^{-1}, the yield increase rates were 7.73%, 6.26% and 19.71%, the average profits increased about 906 yuan ha^{-1}, 689 yuan ha^{-1} and 1423 yuan ha^{-1} respectively in the three regions. In addition, the average yields were higher up to 19.07%, 14.96% and 17.76% respectively when irrigation had been used than without, and it was not the most productive varieties that were the most grown in the three regions. Therefore, the focus of the wheat production in the future must pay more attention to the formulated fertilizer application, conduct rational irrigation and encourage the use of more productive varieties, to provide effective protection for the province and to enhance national food security.

Key words: Formulated fertilizer; Increasing production and income; Irrigation; Varieties; Wheat; China

---

INTRODUCTION

With an increase of population and a decrease of arable land, the contradiction in China between food security and resource consumption and environmental protection is becoming more and more severe[1]. From 1980 to 2011, the total annual grain production increased by 78.19% and inorganic fertilizer application increased by 349.36% in the country. However, the crop-sown area decreased by 5.68% over the same period[2]. The basis of solving the food security pressure is through increasing grain production, which is decided by the food-crop planting area and the per unit area yield of grain. But due to the limitation of arable land, the increase of the grain production can only rely on the improvement of yield[3]. The overuse of inorganic fertilizer, especially synthetic nitrogen fertilizer, in agricultural systems during the last few decades has caused serious consequences in many areas of China[4-8], and it has raised a series of environmental problems[9-11], including nitrate pollution of groundwater, eutrophication of surface water, greenhouse gas emission and other forms of air pollution, acid rain, soil acidification. It has been reported that average soil pH has declined 0.5 units due to the overuse of N fertilizer in the past two decades in China[12]. So how to improve crop yield and reduce environmental risk is an urgent issue which needs to be solve, especially with respects to China.

Fertilization, irrigation and crop varieties are important factors to maintain soil fertility and increase crop yields[13-16]. In addition, wheat is one of the most important food crops throughout the world - the yield and planting area accounts for about a third of the world's food[17]. China is the world's largest production, consumer and importer of wheat, and the development of wheat production has a great significance to the country's food security. Meanwhile, Shaanxi province is one of the major areas of wheat production on a national scale. From a report published by the United Nations, soil testing and formulated fertilization technology is recognized as an environmentally friendly technique[18], and has also been energetically popularized in China in recent years[19].

Thus, our objective of this study was to understand the effects of formulated fertilizer, irrigation and varieties on wheat yield and farmer's income; with the aim to provide the basis for food security measures of the province and the nation.

EXPERIMENTAL SECTION

Study area

Shaanxi province is located in the middle reaches of the Yellow River and the upper reaches of the Yangtze River of the eastern part of northwest China, and it falls between latitudes 31°42′ and 39°35′N, and longitudes 105°29′ and 111°15′E. The area is 2.058×10^5 km^2 and about 880 km from north to south and 160 to 490 km from east to west. The whole province from north to south can be divided into four agro-ecological zones, which are: Loess plateau area of northern Shaanxi, Weibei dry plateau, Guanzhong irrigated area and Qin-Ba mountain area of southern Shaanxi, and in this study abbreviated to North, Weibei, Guanzhong and Qin-Ba respectively. Winter wheat is planted in the last three regions, which is the study area. Main soil types, climatic conditions and soil properties in the different regions are shown in Table 1.

Table 1 Main soil types, climatic conditions and soil properties (average ± Sd) in the different regions

Region	Weibei	Guanzhong	Qin-Ba
Main soil types	Black loess soils, Loess soils	Cinnamon soils	Yellow-cinnamon soils, Yellow-brown soils
Annual mean temperature (℃)	9～13	10～14	11～16
Annual precipitation (mm)	530～630	600～720	670～1270
pH	7.9 ±0.4	7.9 ±0.3	6.8 ±0.9
Organic matter (g kg^{-1})	12.8 ±4.4	15.3 ±7.0	20.6 ±7.9
Alkali-hydrolysable N (mg kg^{-1})	63.3 ±22.7	67.6 ±27.0	115.0 ±49.3
Available P (mg kg^{-1})	14.8 ±11.4	25.9 ±12.5	18.1 ±16.9
Available K (mg kg^{-1})	160.3 ±50.9	165.0 ±60.7	116.6 ±46.4

Data sources: Soil types and climate[20]; Soil chemical properties: data collected by testing centers in the different regions. Unpublished.

Table 2 Distribution of the sites and number of samples investigated and experimented in the study

Region	Counties	No. of conventional fertilization samples	No. of formulated fertilization samples
Weibei	Baishui county, Bin county, Changwu county, Chengcheng county, Chunhua county, Fuping county, Hancheng city, Heyang county, Linyou county, Long county, Pucheng county, Qianyang county, Xunyi county, Yaozhou area, Yijun county, Yongshou county	7348	320
Guanzhong	Baqiao area, Changan area, Chencang area, Dali county, Fengxiang county, Fufeng county, Gaoling county, Hu county, Hua county, Jintai area, Jingyang county, Liquan county, Linwei area, Mei county, Qishan county, Qian county, Qindou area, Sanyuan county, Tongguan county, Weibin area, Weicheng area, Wugong county, Xingping city, Yanliang area, Yangling area	11416	350
Qin-Ba	Baihe county, Chenggu county, Hantai area, Hanyin county, Luonan county, Mian county, Nanzheng county, Shanyang county, Shangzhou area, Xixiang county, Xunyang county, Yang county	2992	100

Data sources

Data used in this analysis was collected from 53 counties from household's conventional fertilization and demonstration trials on formulated fertilization, taken from the project "soil testing and formulated fertilization in Shaanxi province during the years 2007 to 2011". Where, household's conventional fertilization was surveyed by the staff at the Chinese National Soil Testing Stations in Shaanxi province every year, the information from the survey used for this research included: crop varieties, crop yield, fertilizer types, fertilizer rates, and fertilizer application time. At last, the effective survey number was 21756. Demonstration trials were conducted by the staff on representative households' plots every year. The amount of formulated fertilization according to the local situation, and other field managements, were employed using the standard farming practices. At last, the experimental sample size was 770. The distribution of the sites and number of samples investigated and experimented in the different regions is shown in Table 2.

Statistics

Data was analyzed by EXCEL and SPSS16.0 software. In this study, the calculation method of indexes are as follows:

Yield increase rate, % =（Yield of conventional fertilization－Yield of formulated fertilization）/ Yield of conventional fertilization ×100

Increased profit, yuan ha^{-1} =（Production value of formulated fertilization – Costs of formulated fertilization）－(Production value of conventional fertilization – Costs of conventional fertilization)

RESULTS

The nutrient inputs on wheat between conventional and formulated fertilization

The inorganic inputs for wheat were different between conventional and formulated fertilization (Table 3). For the whole province, the average inorganic N, P_2O_5, and K_2O inputs were 183, 110 and 21 kg ha^{-1} respectively under conventional fertilization, while were 146, 96 and 56 kg ha^{-1} respectively under formulated fertilization, which indicated that formulated fertilization had the effect of "decreasing N", "decreasing P" and "increasing K". The laws of it in the three regions were consistent with the whole province. In Weibei, Guanzhong and Qin-Ba regions compared with conventional fertilization, formulated fertilization for N decreased by 31.92%, 12.59% and 10.13% respectively, for P_2O_5 decreased by 20.44%, 2.10% and 26.19% respectively, for K_2O increased by 105.98%, 193.99% and 382.58% respectively. In addition, in accordance with the sown areas in the three regions[21], we calculated if households applied the amount of fertilizers on the basis of formulated fertilization, then in Weibei, Guanzhong and Qin-Ba regions could save N up to 85900 t, 77200 t, 11300 t respectively during wheat growth every year, with the whole province as 169900 t; meanwhile it can also save P_2O_5 up to 36900 t, 8000 t and 19900 t respectively, with the whole province as 64800 t.

Table 3 The nutrient inputs on wheat between conventional and formulated fertilization (kg ha^{-1} ±Sd)

Region	Conventional fertilization			Formulated fertilization		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Weibei	185±83	112±55	23±34	126±46	89±47	47±55
Guanzhong	195±67	115±69	22±33	170±22	113±26	66±27
Qin-Ba	137±56	84±46	11±22	123±24	62±16	51±29
The whole province	183±74	110±63	21±33	146±41	96±39	56±42

The fertilizer costs on wheat between conventional and formulated fertilization

Assuming that using formulated fertilizers will have no effect on pesticides, labour, mechanical power and other important agricultural production factors, under the premise we analyzed formulated fertilization effect on fertilizer input costs for households[19]. In Weibei region, the fertilizer costs averaged 1514 yuan ha^{-1} under conventional fertilization, while formulated fertilization would reduce this to 246 yuan ha^{-1}, averaging at 1268 yuan ha^{-1}. The situation in Guanzhong and Qin-Ba regions shown that the fertilizer costs of formulated fertilization increased 117 yuan ha^{-1} and 52 yuan ha^{-1} respectively, compared with conventional fertilization (Table 4). The reason was that the costs of nitrogen and phosphorus fertilizers both decreased, however the costs of potassium fertilizer increased, which resulted in formulated fertilization not significantly reducing fertilizer input costs.

Table 4 The fertilizer costs on wheat between conventional and formulated fertilization (yuan ha^{-1})

Region	Costs of conventional fertilization				Costs of formulated fertilization			
	N	P_2O_5	K_2O	$N+P_2O_5+K_2O$	N	P_2O_5	K_2O	$N+P_2O_5+K_2O$
Weibei	831	558	126	1514	566	444	259	1268
Guanzhong	877	576	123	1577	767	564	363	1694
Qin-Ba	615	419	59	1092	552	309	282	1144
The whole province	825	548	115	1489	655	481	309	1446

Note: The price of inorganic fertilizer N, P_2O_5 and K_2O are 4.5 yuan kg^{-1}, 5.0 yuan kg^{-1} and 5.5 yuan kg^{-1} respectively.

The fertilization benefit on wheat between conventional and formulated fertilization

In Weibei, Guanzhong and Qin-Ba regions the yields of wheat were 4269 kg ha^{-1}, 6437 kg ha^{-1} and 3742 kg ha^{-1} respectively under conventional fertilization, compared with it the increased yields were 330 kg ha^{-1}, 403 kg ha^{-1} and 738 kg ha^{-1} respectively, the yield increase rates were 7.73%, 6.26% and 19.71% respectively, and the increased profits were up to 906 yuan ha^{-1}, 689 yuan ha^{-1} and 1423 yuan ha^{-1} respectively under formulated fertilization (Table

5). Therefore, although the fertilizer costs under formulated fertilization were higher in some regions (Table 4), the process of optimizing the structure of fertilizer application and production efficiency increased significantly.

Table 5 The fertilization benefit on wheat between conventional and formulated fertilization

Region	Conventional fertilization		Formulated fertilization		Formulated fertilization compared with conventional fertilization		
	Yield (kg ha^{-1})	Production value (yuan ha^{-1})	Yield (kg ha^{-1})	Production value (yuan ha^{-1})	Increased yield (kg ha^{-1})	Yield increase rate (%)	Increased profit (yuan ha^{-1})
Weibei	4269	8539	4599	9199	330	7.73	906
Guanzhong	6437	12873	6840	13679	403	6.26	689
Qin-Ba	3742	7484	4480	8959	738	19.71	1423
The whole province	5334	10668	5602	11204	268	5.03	580

Note: The price of wheat is 2.0 yuan kg^{-1}.

Effect of irrigation on wheat yield

In general, the environment in northwest China belong to arid and semi-arid regions, therefore any agricultural activity is highly dependent on irrigation[22]. In Weibei, Guanzhong and Qin-Ba regions the average yields were significantly higher when irrigation had been used than without, and the yield increase rates up to 19.07%, 14.96% and 17.76% respectively under irrigation (Table 6). It indicated that irrigation had potential to increase wheat yields.

Table 6 Irrigation impact on the yield of wheat

Region	Index	Households	Yield (kg ha^{-1} ±Sd)
Weibei	Non-irrigation	6113	4137±1120b
	Irrigation	1235	4926±1085a
Guanzhong	Non-irrigation	4908	5931±934b
	Irrigation	6508	6818±943a
Qin-Ba	Non-irrigation	2872	3716±972b
	Irrigation	120	4376±652a
The whole province	Non-irrigation	13893	4684±1389b
	Irrigation	7863	6484±1212a

Note: Different lowercase letters indicate the relationship between non-irrigation and irrigation was significant at 5% level in the same area.

Effect of wheat varieties on yield

Apart from using formulated fertilizers and reasonable irrigation, wheat varieties also had a significant impact on the yield. In this study, households used a total of more than 100 varieties. We made statistics on the top 10 varieties in each region and calculated their average yields (Table 7). In Weibei, the yield varied from 3571 to 5320 kg ha^{-1} and the three most productive varieties were Xiaoyan 22, 902 and Changwu 134. In Guanzhong the yield varied from 5763 to 7451 kg ha^{-1} and the three most productive varieties were Yanmai 8911, Xinong 2611 and Zhengmai 9023. In Qin-Ba the yield varied from 2992 to 4524 kg ha^{-1} and the three most productive varieties were Xing 9418, Mianyang 33 and Chuanmai 30. It was interesting to note that it was not the most productive varieties that were the most grown. This indicated a potential of increased yields if the households were encouraged to use the more productive varieties.

Table 7 Different varieties effect on the yield of wheat

Weibei			Guanzhong			Qin-Ba		
Variety	Households	Yield (kg ha^{-1} ±Sd)	Variety	Households	Yield (kg ha^{-1} ±Sd)	Variety	Households	Yield (kg ha^{-1} ±Sd)
Jinmai 47	2280	3571±908f	Xiaoyan 22	5280	6456±1095d	Xinluo 8	618	3220±1055e
Changhan 58	1357	4440±901d	Xinong 979	1338	6395±843d	Xinluo 11	406	3511±1039d
Xiaoyan 22	764	5320±1355a	Xinong 2208	902	6568±990cd	Chuanmai 30	389	4275±487b
Xiaoyan 6	672	4575±1070c	Wunong 148	692	6477±679d	Xin 9418	208	4524±610a
Jinmai 54	593	3724±866e	Yanmai 8911	639	7451±581a	Mianyang 33	195	4281±474b
Changwu 134	474	4707±749bc	Xinong 88	243	6225±867e	Xiaoyan 15	156	3592±991d
Xinong 979	399	4657±1034c	Shanmai 757	237	5579±922f	Mianyang 31	147	3657±799d
Xinong 928	124	4524±627cd	Zhengmai 9023	192	6647±683c	Xiaoyan 22	120	3759±918cd
Tongmai 3	82	4412±1064d	Zhoumai 18	171	5763±1006f	Luo 8 xuan	76	2992±554f
902	81	4926±465b	Xinong 2611	165	6905±629b	Mianyang 19	76	3996±677c

Note: Different lowercase letters indicate the relationship among different varieties were significant at 5% level in the same area.

DISCUSSION

Excessive inorganic fertilization not only wasted resources but also led to many serious environmental problems[11,23-24]. Hence, in order to change the situation of excessive fertilization as soon as possible, it is encouraged and recommended households decrease the fertilizer application rate, especially with nitrogen and phosphorus fertilizers. This is because the lower fertilization rate does not necessarily mean the reduction of yield[25]. For example, a great number of research in rice/wheat rotation systems and winter wheat/summer maize rotation systems has identified that reducing the current N application rates by 30% to 60% could increase N fertilizer efficiency, whilst still maintain crop yields and substantially reduce N losses to the environment[11,26]. Lou et al[27] found that on the basis of households conventional fertilization, reducing N fertilizer by 20% could increase crop yield and quality. Meantime, the research for this paper showed that in Weibei, Guanzhong and Qin-Ba regions compared with conventional fertilization, formulated fertilization for N decreased by 31.92%, 12.59% and 10.13% respectively, for P_2O_5 decreased by 20.44%, 2.10% and 26.19% respectively, while the yield increase rates were 7.73%, 6.26% and 19.71% respectively, and the increased profits were up to 906 yuan ha^{-1}, 689 yuan ha^{-1} and 1423 yuan ha^{-1} respectively. If households used the amount of fertilizers according to formulated fertilization, Shaanxi province could save N 169900 t and P_2O_5 64800 t each year during wheat growing. Zhang[28] reported that every ton of nitrogen fertilizer from production and from fertilizer transportation to farmlands, emitted an equivalent CO_2 up to 12.85 tons in China. Based on that, we calculated the amount of reducing CO_2 emissions was 2.183 million tons from the reduction in nitrogen fertilizer use on wheat on the whole province each year.

"Fertilizer is strength, water is life", reasonable fertilizer and water management is very important factor that affects crop yields, and appropriate levels of irrigation can promote crops growth and development[29-31]. Pei et al[32] found that irrigation quantity had a significant positive effect on increasing wheat yield. Zhang et al[33] also reported that with appropriately increasing irrigation amount, wheat yield can also increase accordingly. The research in this paper showed that in Weibei, Guanzhong and Qin-Ba regions the yield increase rates were 19.07%, 14.96% and 17.76% respectively under irrigation than without. All in all, balanced fertilization and rational irrigation is the key to obtain a high and stable yield and to reduce the environmental risks of dual protection[34-36].

In addition, we also found that it was not the most productive varieties that were the most grown. The high-yielding varieties had more biomass and were more sensitive to the nutrient inputs than the low-yielding varieties, besides high-yielding varieties with high nitrogen and phosphorus fertilizer use efficiency, nitrogen and phosphorus fertilizer agronomy efficiency, nitrogen and phosphorus fertilizer physiological efficiency and nitrogen and phosphorus fertilizer partial factor productivity[37-39]. Ye et al[40] also reported that variety was vital to obtain wheat high yield and super high yield. But nationwide, the proportion of high-yielding and super-high-yielding wheat cultivation was still small, so improving the level of wheat yield, expanding high-yielding and super-high-yielding cultivated area is an important approach to increase the wheat production in the future in China.

CONCLUSION

In Weibei, Guanzhong and Qin-Ba regions compared with conventional fertilization, formulated fertilization for N decreased by 31.92%, 12.59% and 10.13% respectively, for P_2O_5 decreased by 20.44%, 2.10% and 26.19% respectively, for K_2O increased by 105.98%, 193.99% and 382.58% respectively; the increased yields were 330 kg ha^{-1}, 403 kg ha^{-1} and 738 kg ha^{-1} respectively, the yield increase rates were 7.73%, 6.26% and 19.71% respectively, and the increased profits were up to 906 yuan ha^{-1}, 689 yuan ha^{-1} and 1423 yuan ha^{-1} respectively; the yield increase rates were 19.07%, 14.96% and 17.76% respectively under irrigation than without; it was not the most productive varieties that were the most grown. Therefore, the focus of the wheat production in the future must pay more attention to the formulated fertilizer application, along with conducting rational irrigation and encouraging the use of more productive varieties. Therefore, the recommendations identified from this report will help to provide effective protection for food security for the province of Shaanxi and the nation.

Acknowledgment
We thank the Special Fund for Agro-scientific Research in the Public Interest of China (201103003) and the Soil Quality Foundation of China (2012BAD05B03) for their financial support.

REFERENCES

[1] Zhang FS, Wang JQ, Zhang WF, et al. *Acta Pedol Sin*, **2008**, 45(5): 915-924.
[2] Department of Rural Surveys, National Bureau of Statistics. China Rural Statistical Yearbook. China Statistics Press. Beijing, China. **1981-2012**.
[3] Wang JQ, Ma WQ, Jiang RF, et al. *Resour Sci*, **2008**, 30(3):415-422.
[4] Ma WQ. Doctoral dissertation. China Agric Univ, Beijing. **1999**.
[5] Zhang FS, Ma WQ. *Soil Environ Sci*, **2000**. 9(2):154-157.
[6] Richter J, Roelcke M. *Nutr Cycl Agroecosyst*, **2000**, 57(1):33-46.
[7] Wang SR. China Agric Univ, Beijing. **2002**.
[8] Tong YA, Emteryd O, Zhang SL, et al. *Sci Agric Sin*, **2004**, 37(8):1239-1244.

[9] Cui ZL, Chen XP, Zhang FS, et al. *Agron J*, **2008**, 100:517–525.
[10] Cui ZL, Zhang FS, Chen XP, et al. *Field Crops Res*, **2008**, 105:48–55.
[11] Ju XT, Xing GX, Chen XP, et al. *PNAS*, **2009**, 106(9): 3041-3046.
[12] Guo JH, Liu XJ, Zhang Y, et al. *Science*, **2010**, 327:1008-1010.
[13] Smil V. Enriching the Earth: Fritz Haber, Carl Bosch, and the Transformation of Word Food Production. Cambridge: MIT Press. **2001**.
[14] Li QS, Willardson LS, Deng W, et al. *Agric. Water Manage*, **2005**, 71:47-60.
[15] Gong W, Yan XY, Wang JY. *Soils*, **2011**,43(3): 336-342.
[16] Wang J, Liu WZ, Dang TH, et al. *Agron J*, **2013**, 105:143-149.
[17] Wang YT, Li ZM. *Chin Agric Sci Bull*, **2010**, 26(15):353-356.
[18] Ge JH, Zhou SD, Zhu HG, et al. *J Agrotech Econ*, **2010**, 9:57-63.
[19] Zhang F, Han HP. *Jiangsu J Agric Sci*, **2012**, 28(6):1471-1475.
[20] Mei XR, Liu RL. China agricultural environment. Science Press, Beijing, China. **2011**.
[21] Bureau of Statistics of Shaanxi. Shaanxi Statistical Yearbook. China Statistics Press, Beijing, China. **2010**.
[22] Qian ZA, Wu TW, Song MH, et al. *Advan. Earth Sci*, **2001**, 16(1):11-38.
[23] Gao XZ, Ma WQ, Du S, et al. *Chin J Soil Sci*, **2001**, 32(6):258-261.
[24] Wang D, Xu ZZ, Zhao JY, et al. *Acta Agr Scand B-S P*, **2011**, 61:681-692.
[25] Ma WQ, Sisák I. *Ecol Environ*, **2008**, 17(3):1296-1301.
[26]Zhao HB, Wang ZH, Gao YJ. *J Tritic Crops*, **2010**, 30(6):1135-1139.
[27] Lou T, Long HY, Yang LJ, et al. *China J Soil Fert*, **2010**, 2: 11-15, 17.
[28] Zhang FS . **2012**. http://www.stdaily.com/kjrb/content/2012-05/12/content_466842.htm.
[29] Ren HR, Luo Y. *J Irr Drain*, **2004**, 23(4):37-39.
[30] Chen GP, Gao JL, Zhao M, et al. *Acta Agron Sin*, **2012**, 38(1):80-85.
[31] Wang DP, Wu WL, Gu SD, et al. Trans. *Chin Soc Agric Eng*, **2013**, 29(2):1-8.
[32] Pei HW, Sun HY, Shen YJ, et al. *Chin J Eco-Agric*, **2011**, 19(5):1054-1059.
[33] Zhang YP, Wang ZM, Wang P, et al. *Sci Agric Sin*, **2003**, 36(10):1143-1149.
[34]Guo SL, Dang TH, Hao MD. *Agric Res Arid Areas*,**2000**, 18(1):22-27.
[35] Shen RK, Wang K, Zhang YF, et al. *Trans Chin Soc Agric Eng*, **2001**, 17(5):35-38.
[36] Zhang YG, Liu HB, Li ZH, et al. *Plant Nutr Fert Sci*, **2005**, 11(6):711-716.
[37] Cui ZL, Zhang FS, Mi GH, et al. *Plant Soil*, **2009**, 317:267-276.
[38]Zan Y., Wang ZH, Zhou L, et al. *Trans Chin Soc Agric Mach*, **2012**, 43(9):91-98.
[39] Zhou L, Wang ZH, Li FC, et al. *Acta Ecol Sin*, **2012**, 32(13): 4123-4131.
[40]Ye YL, Han YL, Wang WL, et al. *Chin Agric Sci Bull*, **2006**, 22(9):264-267.