

Effects of different mechanized soil fertilization methods on corn soil fertility under continuous cropping

Qingwen Shi^{1,a}, Huixin Wang^{2,a}, Chunming Bai^{2,a}, Di Wu^{1,a}, Qiaobo Song^{1,a}, Depeng Gao^{1,a}, Zengqi Dong^{1,a}, Xin Cheng^{1,a}, Qiping Dong^{1,a}, Yahao Zhang¹, Jiahui Mu¹, Qinghong Chen¹, Wenqing Liao¹, Tianru Qu¹, Chunling Zhang¹, Xinyu Zhang¹, Yifei Liu^{1,*} and Xiaori Han^{1,*}

¹Shenyang Agricultural University, Shenyang, China

²Liaoning Academy of Agricultural Sciences, Shenyang, China

^aJoint first authors

*Co-corresponding author e-mail: liuyifeiscience@163.com

Abstract. Experiments for mechanized soil fertilization for corns were conducted in Faku demonstration zone. On this basis, we studied effects on corn soil fertility under continuous cropping due to different mechanized soil fertilization methods. Our study would serve as a theoretical basis further for mechanized soil fertilization improvement and soil quality improvement in brown soil area. Based on the survey of soil physical characteristics during different corn growth periods, we collected soil samples from different corn growth periods to determine and make statistical analysis accordingly. Stalk returning to field with deep tillage proved to be the most effective on available nutrient improvement for arable soil in the demonstration zone. Different mechanized soil fertilization methods were remarkably effective on total phosphorus improvement for arable soil in the demonstration zone, while less effective on total nitrogen or total potassium, and not so effective on C/N ratio in soil. Stalk returning with deep tillage was more favorable to improve content of organic matter in soil, when compared with surface application, and organic granular fertilizer more favorable when compared with decomposed cow dung for such a purpose, too.

1. Introduction

Since soil is the material basis of crop production, soil fertility magnitude will determine crop growth and yield. Organic fertilizer applied in agricultural production plays its roles mainly in soil improvement, fertilization betterment, and yield gain and quality improvement. Different tillage methods and soil fertilization methods both would affect soil fertility greatly. Mechanized fertilization worked nine times faster than traditional fertilization, so it was able to save labor resource, and both were not so significantly different in terms of greenhouse gas emission [1]. Therefore, mechanized fertilization is of higher promotional value in a way. Stalk returning to field was able to increase organic matter in soil and improve nitrogen use efficiency for the purpose of high yield eventually [2,3]. Compared with the use of stalk, farmyard manure was more favorable to the accumulation of potassium and SOM in limestone soil [4, 5]. As research indicated, culture substrate with decomposed cow dung as the main material was able to improve substrate volume weight, total porosity, along with



the growth and physiological indicators of pepper seedlings [6, 7]. Chemical fertilizer when applied could improve soil fertility to some degree, but it was not so remarkably effective. As some studies indicated, normal farmyard manure when applied was featured with more greenhouse gas emission than chemical fertilizer. However, organic granular fertilizer was effective to increase yield with persistent fertilizer efficiency for soil fertilization, and this was not only favorable to increase after crop production proportionately, but to optimize ecology as well [1,8-9]. Broadcast application will not give full play to the organic granular fertilizer, and it will only reduce application effects. Then if furrow application or whole application is assumed, better effects may be expected.

2. Material and method

2.1. Experimental material

2.1.1. Corn variety for experiment: Shenghe 18

2.1.2. *Soil type*: It is brown soil, located in Lujiafangshen Village, Dagujiazi Town, Faku County. The physical and chemical properties of the soil for test are listed in the following tables:

Table1 The physical-chemical properties of soil before seeding in 2014

Treat.	Organic matter (C g·kg ⁻¹)	Total N (N g·kg ⁻¹)	Total P (P g·kg ⁻¹)	Total K (K g·kg ⁻¹)	Alkali-N (N mg·kg ⁻¹)	Olsen-P (P ₂ O ₅ mg·kg ⁻¹)	NH ₄ OAc-K (K ₂ O mg·kg ⁻¹)	Bulk density (g/cm ³)	PH
Content	11.89	2.27	0.12	15.93	100.78	19.28	86.83	1.39	5.06

2.1.3. *Fertilizer for test*: (1)Organic fertilizer: decomposed cow dung at the local cattle farm (nutrient content: organic carbon 33.81%, N content 2.41%, P₂O₅ content 1.919%, K₂O content 1.445%,moisture 58.29%).

(2)Corn stalk: local corn stalk (nutrient content: organic carbon 43.54%,N content 0.863%, P content 0.260%, K content 0.834%, moisture 9.07%).

(3)Granular fertilizer as biochar-based: granular fertilizer as biochar-based from the Plant Nutrition and Fertilizer Research Institute of Shenyang Agricultural University (moisture 25-30%,organic matter≥45%,NPK≥5%,nitrogen 2.06%,phosphorus 1.82%,kalium 1.78%, secondary and microelements≥26%).

(4)Conventional chemical fertilizer: slow release fertilizer with the brand of Qingyuan, which was used as the base fertilizer for deep placement, 50kg per mu (≈667m², Chinese traditional unit area and the same below) (NPK content of 27-11-13, zinc 0.02% for the product made by Changjiang Controlled Release Fertilizer Company Ltd., Jilin). Seed fertilizer for surface application: Compound fertilizer of 15-15-15 with the brand of Yanyangtian.

(5)Microbial agent: stalk decomposing agent applied for stalk returning to field.

2.1.4. *Machinery for test*: (1) HP 55/60 tractors and plowing, harrowing, ridging as well as sowing equipment.

(2)Stalk returning equipment: mechanical stalk cutting (5-10cm long), returning to field by manual work.

(3)Broadcaster for granular chemical fertilizer: single disc broadcaster as developed by Nanjing Agricultural Mechanization Research institute of the National Agriculture Ministry.

(4)The spraying machines and equipment for field fertilizer, pesticide and microbial agent shall be operated conventionally as farmers usually do.

2.2. Test Method

On the premise of the same plot with the same soil fertility under the same tillage conditions, five experimental zones were established for our experiments: Zone I (with mechanical broadcasting of

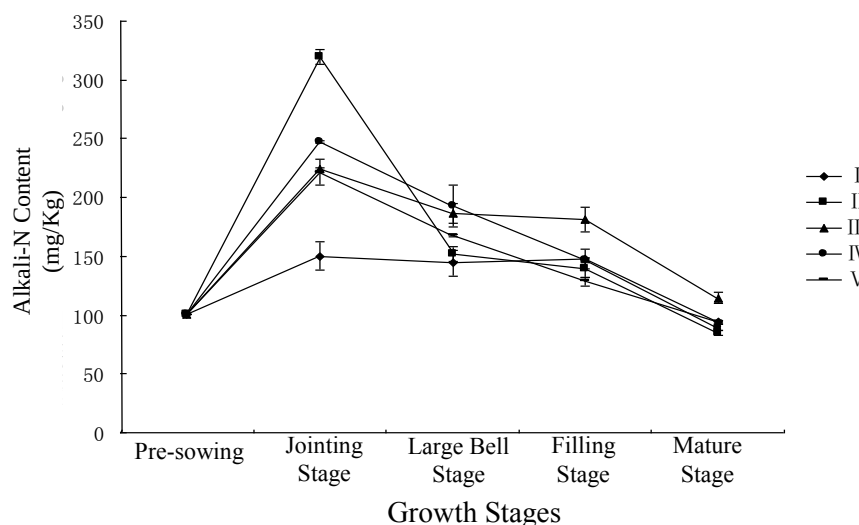
decomposed cow dung, 500kg each mu as air-dried basis, moisture 20%, rotary tillage for 20cm on ridges); Zone II (mechanical cutting and crushing for stalk returning and surface application, 400kg per mu, with stalk decomposing agent and chemical nitrogen fertilizer to be used together and sprayed at the same time according to the single factor, then rotary tillage on ridges for 20cm); Zone III (mechanical cutting and crushing for stalk returning first and deep tillage for 30cm further, 400kg per mu, with stalk decomposing agent and chemical nitrogen fertilizer to be used together and sprayed at the same time according to the single factor); Zone IV (mechanical broadcasting of granular fertilizer as biochar-based) and Zone V (conventional management of tillage and fertilizer application, for which 18kg nitrogen, 5kg phosphorus pentoxide, 6kg potassium oxide, urea and potassium chloride 20kg+10kg as the basic fertilizer, 10kg diammonium phosphate as the seed fertilizer, extra fertilization for 225kg/hm at bell stage, or special fertilizer for corns would be selected, and due to stalk returning practice, potash fertilizer amount could be properly reduced).

These experiments started from the year of 2013, and then soil samples were collected in autumn to determine their volume weight, organic matter content and nutrients. Then fertilizer and stalk composition were under analysis. Tasks after crop harvesting or before sowing included stalk returning, broadcasting of organic fertilizer, chemical fertilizer and microbial agent, and soil tillage as well. Soil samples and plant samples were collected according to growth periods (before fertilization and tillage, at elongation stage, at bell stage, at filling stage and at ripe stage).

3. Results and analysis

3.1. Effects on available nutrients of arable soil for corns during their different growth periods due to different mechanized soil fertilization methods

At ripe stage, contents of alkali-hydrolyzable nitrogen, available phosphorus and available potassium in topsoil in zone III were all remarkably higher than those with other treatments. This was because stalk returning with deep tillage was able to improve soil structure and accelerate microorganism reproduction and stalk decomposition, then facilitating release of available nutrients. In case of stalk returning and surface application, release of alkali-hydrolyzable nitrogen was quicker, though not so persistent. Available potassium in the decomposed cow dung enjoyed quicker release than the available potassium in the organic granular fertilizer did. Therefore, when compared with surface application, deep tillage helped to improve available nutrients in soil after stalks were crushed and returned to field.



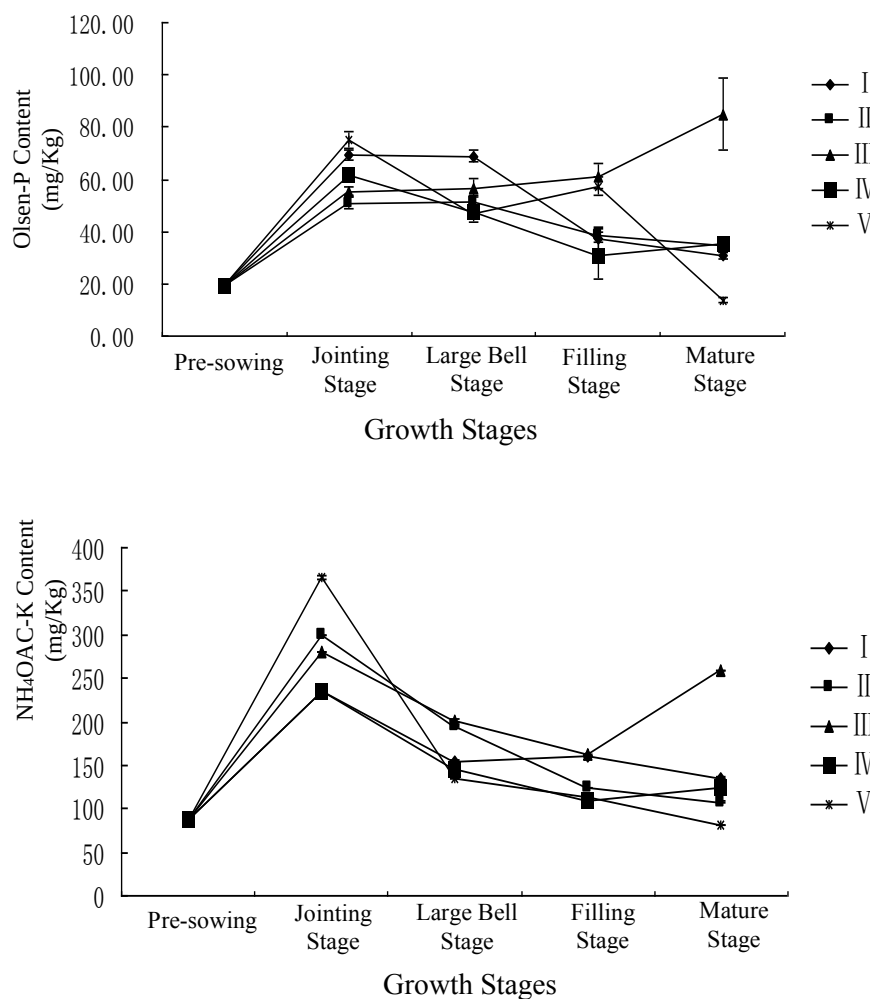


Figure 1. Changes of the contents of soil available nutrients in each growth stage of maize

3.2. Effects on soil total nutrients, organic matter and C/N for corns at their ripe stage due to different mechanized soil fertilization methods

As compare with situations before fertilization and tillage, total nitrogen and total phosphorus at the arable soil in zone I, zone II, zone III and zone IV increased for 3.19% and 127.71% respectively, while total potassium reduced for 0.91% on the average. Mechanical deep tillage, if combined with crushed stalk returning, was beneficial to improve total nitrogen content at topsoil. Additionally, stalk returning when combined with surface application was able to remarkably improve total phosphorus content at topsoil.

Mechanical deep tillage, when compared with surface application, was able to remarkably improve organic matter content in soil. So were organic granular fertilizer when compared with decomposed cow dung, and organic granular fertilizer when compared with conventional fertilizer application. organic matter content in arable soil in zone I, zone II, zone III and zone IV increased for 21.32% on the average, when compared with the situations before fertilization and tillage. Mechanical deep tillage and fertilization did not remarkably influence soil C/N ratio, when compared with conventional fertilization.

Table2 Effects of different treatments on Total nutrient of soil in maize mature stageDuncan^{a,b}

Treat.	Total N(g/kg)		Total P(g/kg)		Total K(g/kg)	
	0-20cm	20-40cm	0-20cm	20-40cm	0-20cm	20-40cm
I	1.89±0.11b	2.19±0.28a	0.321±0.012b	0.157±0.009a	15.794±1.055a	15.238±1.100a
II	2.32±0.51ab	2.13±0.13a	0.372±0.003a	0.170±0.005a	15.239±0.858a	15.017±0.144a
III	2.65±0.20a	2.41±0.13a	0.221±0.002c	0.155±0.016a	16.732±0.435a	15.160±1.335a
IV	2.51±0.58ab	2.08±0.12a	0.179±0.002d	0.161±0.007a	15.377±0.491a	15.137±0.225a
V	2.27±0.32ab	2.08±0.09a	0.176±0.007d	0.154±0.005a	16.474±0.767a	15.839±0.435a

Note: Different letters in the same column mean significant difference at 5% level.

Table3 Effects of different treatments on topsoil Organic matter and C/N in maize mature stageDuncan^{a,b}

Treat.	Organic matter(g/kg)		C/N	
	0-20cm	20-40cm	0-20cm	20-40cm
I	13.41±0.42cd	10.90±0.76c	4.12±0.27a	2.93±0.58b
II	12.07±0.67d	9.80±0.27d	3.13±0.78a	2.67±0.23b
III	17.01±0.59a	11.14±0.43bc	3.74±0.42a	2.69±0.25b
IV	15.21±1.07b	13.09±0.13a	3.67±1.01a	3.67±0.25a
V	13.52±0.66c	11.96±0.13b	3.51±0.61a	3.33±0.18ab

Note: Different letters in the same column mean significant difference at 5% level.

4. Conclusion

4.1. Mechanization remarkably was effective on available nutrient increase in soil in the demonstration zone.

Alkalihydrolyzable nitrogen enjoyed its quicker release in case of stalk returning and surface application, though not so persistent. Available potassium in the decomposed cow dung enjoyed quicker release than the available potassium did. Stalk returning with deep tillage, if compared with surface application, was more beneficial to improve available nutrient content in soil.

4.2. Mechanization remarkably affected total phosphorus improvement for the arable soil at the demonstration zone.

However, it was less effective on and total nitrogen and total potassium. Crushed stalk returning combined with deep tillage, in addition to decomposed cow dung application, was able to remarkably improve total phosphorus content at topsoil.

4.3. Mechanization did not remarkably influence soil C/N ratio for the arable soil in the demonstration zone.

As compared with conventional fertilization, crushed stalk returning with deep tillage, when organic granular fertilizer broadcasting was also adopted, was able to remarkably improve organic matter content at topsoil. Mechanical deep tillage, when compared with surface application, was more beneficial to improve organic matter content in soil, and so was organic granular fertilizer when compared with decomposed cow dung application.

Based on the analysis above, it is concluded that crushed stalk returning with deep tillage for 30cm is able to remarkably increase the available nutrient content in brown soil at the corn continuous cropping area. Organic granular fertilizer, when compared with decomposed cow dung, is more beneficial to improve organic matter content at topsoil. Thus, for brown soil at the corn continuous

cropping area, it is advised that crushed stalk returning combined with deep tillage, in addition to organic granular fertilizer broadcasting by agricultural machinery shall be adopted for management. This practice shall not only remarkably increase soil available nutrient in arable soil, but also improve organic matter content to the effect of loose soil structure and local soil fertility betterment.

Acknowledgments

This work was financially supported by Natural Science Foundation of China (31301842; 31601627), National science and technology support project (2013BAD08B04), Cultivation Plan for Youth Agricultural Science and Technology Innovative Talents of Liaoning Province (2014043), Program of Liaoning Excellent Talents in University (LJQ2015100), China Scholarship Council (CSC NO. 201708210143) and National Peanut Research System (CARS-14).

References

- [1] Alfred Gathorne-Hardy. The sustainability of changes in agricultural technology: The carbon, economic and labour implications of mechanisation and synthetic fertiliser use. *Ambio*, 45(2016)885-894.
- [2] Jianling Pan, Wanan Dai, Zhanhuan Shang, et al. Effects of straw returning on soil organic matter and nitrogen availability and its mechanism. *Chinese Journal of agricultural ecology*. 05(2013)526-535.
- [3] Ru Zhang. Design of multifunctional straw returning machine and experimental study on its performance. Northeast Agricultural University, 2014.
- [4] Wei Zhang, Hongsong Chen, Yirong Su, et al. Effects of different fertilization on crop and soil fertility in newly reclaimed lime. *Chinese Journal of Soil Science*, 04(2013)925-930.
- [5] Jie Li, Mingliang Wu, Yuanju Tang, et al. Research status and development trend of organic fertilizer application machinery. *Journal of Hunan Agricultural University(Natural Science Edition)*, S1(2013)97-100.
- [6] Jing Li, Jihua Yu, Jianming Zhe, et al. Effect of seedling amount of cow manure compost on pepper seedling quality. *Journal of Gansu Agricultural University*, 04(2012)38-42.
- [7] Chikowo R, Mapfumo P, Nyamugafata P, et al. Maize productivity and mineral N dynamics following different soil fertility management practices on a depleted sandy soil in Zimbabwe[J]. *Agriculture, Ecosystems & Environment*, 102(2004)119-131.
- [8] Yongling Sun, Fengxiang Chen. Preliminary report on high yield cultivation of hybrid rape with particulate organic fertilizer. *Anhui Agricultural Science Bulletin*, 17(2009)74-75.
- [9] Lyimo H J F, Pratt R C, Mnyuku R S O W. Composted cattle and poultry manures provide excellent fertility and improved management of gray leaf spot in maize[J]. *Field Crops Research*, 126(2012):97-103.