

Effects of different mechanized soil fertilization methods on corn nutrient accumulation and yield

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Abstract. Aim: Experiments for mechanized corn soil fertilization were conducted in Faku demonstration zone. On this basis, we studied effects on corn nutrient accumulation and yield traits at brown soil regions due to different mechanized soil fertilization measures. We also evaluated and optimized the regulation effects of mechanized soil fertilization for the purpose of crop yield increase and production efficiency improvement. Method: Based on the survey of soil background value in the demonstration zone, we collected plant samples during different corn growth periods to determine and make statistical analysis. *Conclusions:* Decomposed cow dung, when under mechanical broadcasting, was able to remarkably increase nitrogen and potassium accumulation content of corns at their ripe stage. Crushed stalk returning combined with deep tillage would remarkably increase phosphorus accumulation content of corn plants. When compared with top application, crushed stalk returning combined with deep tillage would remarkably increase corn thousand kernel weight (TKW). Mechanized broadcasting of granular organic fertilizer and crushed stalk returning combined with deep tillage, when compared with surface application, were able to boost corn yield in the demonstration zone.

1. Introduction

Nowadays, poor mechanization applicability and unreasonable use of organic fertilizer prevail in agricultural production. Extensive cultivation and abuse of chemical fertilizer lead to soil nutrient imbalance and soil fertility decline, so crop nutrient accumulation and yield are impacted [1,2]. Therefore, it is very pressing to study and implement effective measure to improve soil fertility. Alfred Gathorne-Hardy, based on his study from a prospective of sustainable development, found out that mechanization was featured with higher efficiency than cattle ploughing as labor-saving, and both were not so significantly different in terms of greenhouse gas emission [3, 4]. Mechanized deep placement could facilitate rice tillering, favorable for rice root system elongation to absorb nutrients, so rice yield increased consequently [5]. Mechanized deep placement as adopted in Japan proved that it was effective for yield increase. It was reported that as for deep placement 35 days prior to rice



heading at the agricultural experimental station of Aomori, Japan, nitrogen use efficiency even amounted to 86%. Koyama and others (1973) found that the applicability of nitrogen for whole layer placement was twice as much as that for surface application. Vachhani (1952) stated out that as for granular fertilizer, deep placement around paddy plants was more effective than surface application. Prasad and others (1970) also confirmed that deep placement of nitrogenous fertilizer was better than surface application both in terms of paddy yield and nitrogen uptake [6]. As some studies indicated, when organic granular fertilizer (Aike brand) was combined with urea and potassium sulfate as a practice of mixed application, it was able to increase paddy yield; while there was not so significant difference in paddy yield between organic granular fertilizer of exclusive application (Aike brand) and conventional fertilization [7]. Liu Shujie during his study confirmed that mechanical deep placement of chemical fertilizer was able to increase paddy yield remarkably, and this practice would save fertilizer as well [8]. Research showed that mechanize deep placement of chemical fertilizer was able to increase paddy yield and save fertilizer, too [9, 10].

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 Lujiangfangshen 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	Total N	Total P	Total K	Alkali-N	Olsen-P	NH ₄ OAc-K	Bulk density	PH
	(C g·kg ⁻¹)	(N g·kg ⁻¹)	(P g·kg ⁻¹)	(K g·kg ⁻¹)	(N mg·kg ⁻¹)	(P ₂ O ₅ mg·kg ⁻¹)	(K ₂ O mg·kg ⁻¹)	(g/cm ³)	
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 ammonium 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. Mechanization effects on nutrient accumulation for corns during their different growth periods

Table2 Effects of different treatments on N accumulation in different growth stages (kg/mu)

Treat.	Total N(kg/mu)			
	Jointing stage	large bell stage	Filling stage	Mature stage
I	0.429±0.019a	8.509±0.378c	7.939±0.886b	13.574±0.347a
II	0.360±0.011c	9.265±0.394bc	7.327±0.733b	10.983±0.092bc
III	0.296±0.007d	10.375±0.907ab	6.625±0.403b	12.246±0.800b
IV	0.388±0.033bc	9.867±0.605ab	9.678±0.694a	10.908±1.206c
V	0.409±0.015ab	10.722±0.496a	10.552±0.341a	11.515±0.160bc

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

Table3 Effects of different treatments on P accumulation in different growth stages (kg/mu)

Treat.	Total P(kg/mu)			
	Jointing stage	large bell stage	Filling stage	Mature stage
I	0.075±0.010a	2.516±0.129ab	3.070±0.815a	3.521±0.563ab
II	0.068±0.006a	1.981±0.182c	2.313±0.362b	3.001±0.039bc
III	0.040±0.003b	2.420±0.321b	1.874±0.126b	4.212±0.423a
IV	0.064±0.005a	2.785±0.103a	1.924±0.187b	2.650±0.252c
V	0.065±0.007a	2.553±0.176ab	2.295±0.313b	3.179±0.337bc

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

Table4 Effects of different treatments on K accumulation in different growth stages (kg/mu)

Treat.	Total K(kg/mu)			
	Jointing stage	large bell stage	Filling stage	Mature stage
I	0.750±0.099a	19.297±0.274a	2.548±0.676a	15.277±0.445a
II	0.602±0.008b	14.591±0.152c	1.919±0.301b	9.479±0.437c
III	0.453±0.016c	14.017±1.617c	1.555±0.105b	12.564±0.215b
IV	0.775±0.062a	16.707±0.712b	1.597±0.156b	8.537±0.246d
V	0.627±0.026b	9.759±0.272d	1.904±0.259b	8.296±0.301d

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

As indicated from table 2, 3 and 4, we could perceive that nitrogen accumulation and potassium accumulation per unit area in treatment I was 17.88% and 84.15%, respectively higher than N and K accumulation per unit area in treatment V. Treatment III, when compared with treatment II, remarkably increased phosphorus and potassium accumulation per unit area at corn ripe stage. Both treatment I and treatment III remarkably increased nitrogen, phosphorus and potassium accumulation per unit area inside plants at corn ripe stage, when compared with conventional cultivation and fertilization.

3.2. Mechanization effects on yield traits for corns at their ripe stage

Table5 Effects of different treatments on yield characters of maize in mature stage

Treat	Bald tip length/cm	Ear length/cm	Ear diameter/cm	Corn cob diameter/cm	Rows per ear	Kernel numbers per ear	1000-kernels weight/g	Yield/kg/mu
I	0.716±0.095a	18.49±0.32ab	5.387±0.065a	2.911±0.199a	18.0±0.40a	671.7±6.0b	390.33±2.75c	843.80±13.23b
II	0.443±0.124b	18.86±0.47ab	5.381±0.044a	2.797±0.028a	18.1±0.46a	653.3±12.5c	397.33±1.53b	903.07±9.98a
III	0.307±0.073b	18.71±0.38ab	5.422±0.073a	2.912±0.037a	18.1±0.46a	685.3±3.2b	413.00±1.80a	807.72±2.95c
IV	0.257±0.055b	18.12±0.87b	5.415±0.154a	2.898±0.112a	18.7±0.83a	671.3±7.1b	399.17±3.21b	836.93±3.87b
V	0.270±0.068b	19.30±0.06a	5.405±0.045a	2.875±0.045a	18.0±0.40a	704.0±5.0a	385.77±0.75d	845.73±6.85b

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

Indication from Table 5: bare top length in treatment I was remarkably different from that of the other four treatments. Ear length of treatment I, treatment II, treatment III and treatment V were roughly identical. Ear diameter, cob diameter and ear rows for each treatment were basically identical. Grain number per panicle of treatment V was remarkably larger than that of the other four treatments. Thousand kernel weight (TKW) of treatment I, treatment II, treatment III and treatment IV were remarkably higher than that of treatment V. This means that these four methods of mechanized soil

fertilization were all able to remarkably increase corn TKW, compared with conventional cultivation and fertilization. Among them, treatment II enjoyed the highest yield, remarkably different from that of the other treatments. This is also to indicate that crushed stalk returning with surface application, when compared with deep tillage or conventional cultivation and fertilization, could better increase corn yield in the demonstration zone.

4. Conclusion

1. Decomposed cow dung, when under mechanical broadcasting, was able to increase nitrogen and potassium accumulation per unit area in plants for corns at their ripe stage. Crushed stalk returning combined with deep tillage would remarkably increase phosphorus and potassium accumulation content in plants for corns at their ripe stage. For decomposed cow dung under mechanical broadcasting and stalk returning combined with deep tillage, both were able to remarkably increase nitrogen, potassium and phosphorus accumulation per unit area in plants for corns at their ripe stage.

2. Compared with conventional cultivation and fertilization, decomposed cow dung and organic granular fertilizer under mechanical broadcasting, as well as crushed stalk returning with deep tillage and surface application, were able to remarkably increase corn TKW. Compared with deep tillage and conventional cultivation and fertilization, crushed stalk returning with surface application could remarkably increase corn yield in the demonstration zone.

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