Inorganic nutrients management system through intelligent compounds to promote sustainable agriculture in South China

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Abstract

Contribution of inorganic nutrients from chemical fertilizer (CF) to increment the food production is about 50% in China. The investment of the inorganic nutrients has been half of total material input of Chinese farmers at present. However, sustainable agricultural production in China faces serious challenge because of low efficiency of nutrients use, especially N. The reason of the low N use efficiency is as followings. Firstly, there is a great gap between theory and technology of balanced fertilization and extension of the theory in farming. Secondly, CF especially compounds produced are divorced from both plant demand and soil fertility. Thirdly, quality of locally made compounds is poor. Finally, so called specialty compounds are not specialized. Therefore, inorganic nutrients from CF may lose into ground, surface water system or accumulated into soil to cause environmental problem as a side effect. In order to realize sustainable agricultural production and to increase nutrients utilization efficiency we have concentrated on developing technique to manufacture a series of specialty compounds (SSC) as loader or carrier of balanced fertilization theory and technology to establish an intelligent nutrients management system. The effect of the system on litchi, hot pepper, rice and winter wheat production, on N use efficiency and mechanism of the effect were discussed.

Results of litchi trials showed that yield of litchi treated with specialty compounds increased from 17% to 37% for 8 years old trees and 19% to 40% for 5 years old trees compared to normal fertilization management system respectively. Field experiments showed that rice yield increased about 16.5%. However, inorganic NUE increased 40% after urea treated into multiple coating ureas as controlled release fertilizer in comparison with normal urea. The reason is that velocity of N supply of the coated urea is significantly lower than that of normal urea. The velocity coefficient k (dynamics constant) of the coated urea is 0.3148 and the normal one is 0.3865. Therefore, both CRF and the intelligent compounds or intelligent nutrients management system are achievements integrating soil fertility and plant nutrition and fertilization to promote balanced fertilization in farming practice.

Keywords: intelligent nutrient management system, intelligent compound, fertilizer use efficiency, balanced fertilization, and multiple coating urea (MCU), CRF

Introduction

Chemical fertilizer, one important agricultural production raw material, has been crucial in agro-production that can be imagined by its continual increase of output. According to the report of FAO chemical fertilizer accounts for 30% increase of total grain food and 55% of per unit area over the world. Results of more than 5000 field trials from Chinese national fertilizer net work over the last 20 years indicate that yield of rice, corn, winter wheat, rapeseed, cotton and beet in chemical N and P combination or N, P and K combination treatments increase 40.85%, 46.1%, 56.6%, 64.5%, 48.6% and 44.2% respectively compared with no chemical fertilizer treatments. In average, balanced fertilization treatment increases about 50% of grain yield per unit land and 1/3 of total grain yield in China (Lin and *et al.,* 1999). Investment of inorganic nutrients from chemical fertilizer covers the majority portion of the total investment of Chinese farmers, the investment of the inorganic nutrients from chemical fertilizer has been half of total input materials of Chinese farmers at present (Zhu, 1998). However, this costly input inorganic nutrient from chemical fertilizer has not used efficiently. The nitrogen, phosphorus and potassium use efficiency is about 30% to 35%, 10% to 20% and 35% to 50% respectively over China (Zhu, 1998). Loss of these nutrients not only causes loss of money, but also causes environment pollution. Considering the economic strength of the nation and agricultural science progress, along with the effort to increase production and importation for adequate demand, great attention is needed to further improve fertilizer efficiency by materializing theory and technology of balanced fertilization (TTBF). The principle and method how to promote the TTBF through materializing the theory and technology is discussed in this paper based on our research results and the others' view in the literature.

Materials and Methods

Litchi and fruit vegetable field trials

Litchi field trials have been carried out in both west part (WP) and east part (EP) of Guangdong province standing for two different eco-systems. Treatments of the experiment included a series of specialty compounds such as high N compound (SC1), high PK compound (SC2) and high K compound (SC3). The trials used regression orthogonal design. The upper level per tree was 3, 1.5, 1.5 kg, and the lower level per tree was 1, 0.5, 0.5 kg compound of SC1, SC2, SC3 respectively. Each treatment arranged 667 m^2 and 20 trees for 20 duplications. SC1, SC2 and SC3 used in June, November and next March respectively in WP, and then in July, December and next April in EP. After harvest litchi yield, water-soluble sugar content was tested.

Hot pepper trials were carried in southwester Guangdong. SC1, SC2, and SC3 were used during vegetable growth.

Cereal crop field trials

Rice field tests were carried out on farm of South China Agricultural University. Winter wheat trials carried out in Shaanxi province in north China. Fertilizer included multiple coating urea (MCU) as controlled fertilizer, normal urea (NU), Gypsum urea (GU) 100% basal and splitting application. . NPK formula was 2-1-1 for rice in the trial. Fertilization rate is 150 kg N, 75 kg P_2O_5 and 75 kg K_2O ha^{-1}. In splitting treatment P and K fertilizer was used as base and 50% of N as base and the other 50% being divided into two parts for top dressing evenly.

Fertilizer types and NPK formula were the same as rice for winter wheat trials. Fertilization rate was 200 kg N, 100 kg P_2O_5 and 100 kg K_2O ha^{-1}. MCU was the controlled release fertilizer treatment. Urea, super-phosphate and KCl were NPK resources for BB treatment. They were mixed and used as basal once time. CRF, being multiple coating urea (MCU), was also used as basal once time. Another treatment was local average (LA), standing for local fertilization habit of which the average NPK ratio was 165 N kg ha^{-1}, 108 P_2O_5 kg ha^{-1}.

Entirety design was applied. Plot size was 30 m^2 and 4 replicates for rice in 1999 and 2000. Plots size was 400 m^2 and 9 m^2 of protected area for harvest and 6 replicates for winter wheat field experiment in 1999 and 2000. Yield and nitrogen uptake was determined after harvest.

Dynamics of N supply of MCU

Dynamics of N supply of MCU was studied by use of improved incubation method (Fan, 2001) according to Stanford and Smith (1972). Two grams MCU as CRF mixed with 60 g soil and incubated under 35ºC constant temperature. Every incubation tuber was leached by 100 ml 0.02 mol/L $CaCl_2$ solution at 7d, 14d, 21d, 28d, 35d, 42d, 49d, 56d, 63d, 70d, 77d and 84d. The leachate was collected and stored at 25ºC for Nmin test. The dynamic equation is as followings (Fan, 2001).

$$\ln(N_o - N_t) = \ln N_o - kt$$

Results and Discussion

Present situation and existing problems of fertilizer and fertilization in China

New trend of demand for fertilizer in China

During the course of fast development of chemical fertilizer in China there are following three characteristics or trends for fertilizer demand.

1. The inorganic fertilizer production transfers from mono-element fertilizer to compound and from low-concentration to high concentrated compounds. For example, the total production of NPK compound was only 3.5 million ton in 1999 in China. However, the output of the NPK compound increased 43%, being 50 million tons at the end of September in 2000. Figure 1 shows that although total amount of N fertilizer has been the highest among NPK mono-element fertilizer and NPK compounds, both measured and predicted average annual increasing rate of NPK compounds is the biggest one. The annual increasing rate of N, P, K and compound was 5%, 5%, 14% and 18% respectively for last 20 years. According to our investment before 2000 the concentration of the NPK compounds was ranged from 25% to 35%, and it is from 35% to 45% at present because the concentrated compounds are easier and cheaper to transport and apply.

2. Techniques of compound manufacture shifts from simple bulk blending (BB) into chemical compound. The history of compound production in China might be divided into three phases. Most of the compound was BB in 1980's before farmers in a large scale accepted it. In 1990's two element nutrients chemical compound technique was put forward to practice, such as AMP and ADP in China. In the same decade NPK mixture compound technique was the main technique to produce three elements compound in China. The so-called mixture compound technique is a secondary processing technique. Here it is named finely bulk blending (FBB) because the raw

material is almost the same as BB compound. The only difference is to grind each mono-element fertilizer and re-make granules after mixture. Since the end of 1990's the chemical compound manufacture technique is more and more popular in China. There are several jointing chemical compound plants which have been built since end of last century, such as KCF, being KEMIRA Chemical Factory cooperated with Zhangjiang chemistry industry cooperative in China. The quality of the products of the three phases is in the order of Chemical compound > FBB > BB.

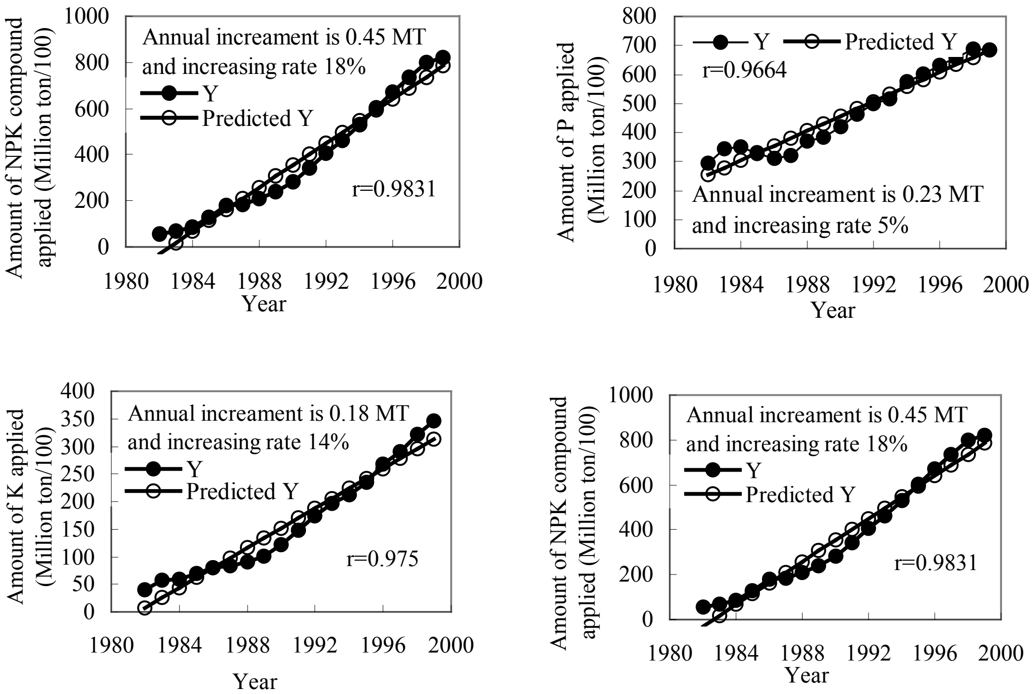

Figure 1 Measured and predicted amount of NPK mono-element nutrient and NPK compounds of inorganic fertilizer has been applied and their increasing rate since 1980 in China.

3. Enterprises grow from small workshops to large scale and professional plants. Decrease of price superiority of compound gradually, increase of competition among enterprises and decline of profit are the results of shifting the planned economy to a market economy along with entering the WTO. Therefore, the small scale workshops face conjuncture of surviving at present. The only way to increase their force to survive in competition is to develop high-tech products and to enlarge production scope to ensure the compound production being on the base of profession and large scale. Several fertilizer plants have recognized this point and tried to get benefits from professional and abundant production. For example, Kemira Chemical Factory (KCF) in Zhangjiang, Sino-Arabia Chemical Factory (SACF) in QinhuangDao and Hongri Chemical Factory in Shangdong with annual output about 0.3 to o.6 million tons are three largest chemical plants built in the ninth five years plan in China. There are now another four big chemical compound plants with an annual output estimated about 0.3 million tons under construction in China (Xu, 1999).

Production amount is the foundation of professional production of a fertilizer plant. Professional production will ensure compound quality that includes amount of total nutrients, concentration of mono-element in it, form of nutrients, ratio of NPK and amount and variety of additives. The reason why imported compounds are popular and used in a large scale along coastline in China is its high quality although its price is much higher than local mixture compound. Xu (1999) reported that United State had about 3000 compound factories in 60's to 70's last century being the same situation in China today and there are about 20 large scope compound plants at present. China will follow the same route (Feng, 1998).

Current situation and problems existed in theory and technology of balanced fertilization and compound production

Compound fertilizer itself should be media material or carrier of TTBF, and the compound fertilizer plant should act as a master who materializes the TTBF into the carrier not just treats the compound as nutrient itself. In brief such a compound fertilizer is named TTBF carrier (TTBFC) and the plant named TTBF materialization master (TTBFMM) in the context. However, currently more than 2000 compound fertilizer plants over China have not acted as the TTBFMM and the products have not become the TTBFC yet because of the following reasons.

1. Disjuncture of theory and practice of balanced fertilization. Although the theory and technique of balanced fertilization has been consummate gradually for the last 20 more years study, there has been a big gap between the theory and technique and its application in farming practice. The reason why the gap still existed is that there is no such qualified compound fertilizer that is able to act as the carrier of TTBF at present. In fact compound in the markets is mainly the carrier of NPK nutrients. Fertilizer use efficient, especially N use efficiency is still low as a side effect.

2. Production does not fit the requirement. Since opening fertilizer market in 1990s chemical fertilizer manufacture has mainly paid attention to profit rather than to agro-chemistry service after sales. Manufacture of compound fertilizer has been adjusted mainly by market profit, which not only causes blind production but serious disjuncture between manufacture and demand in agro-production. Majority portion of compound plants, especially small and middle scale ones are devoid of knowledge of TTBF, plant nutrition and soil fertility. In addition, they are out of support of professional institutes such as research institute and universities. Therefore, the NPK formula is not fit for plants growth and the quality of compounds is no guarantee. In some instances and extent fake compound appeared and lead farmers to misunderstand TTBF because copies always have a TTBF mask. Thus a proportion of farmers have abandoned the TTBF insensibly (Fan, 1998).

Almost all of the compound fertilizer plants have not recognized that the only way to obtain great profit and to promote its production is to treat them as TTBFMM and to treat the compound as TTBFC. For example one of the big compound plants has registered more than 30 types of compounds. However, disquieting thing is that the main difference is the colorful package rather than compound itself. Though the plant only thought that a colorful package would attract farmers' attention to buy its products at the moment, it has not known that quality of products is the only way to win the market finally.

Problems caused by extreme specialty and overabundance of specialty compounds

According to a fertilizer glossary in United States specialty compound (SC) is defined as fertilizer applied to roses, grassland, ornamental plants and the other non-field crops (Xi, 1994). However, the SC is termed as compound applied to a kind of crop in a given regions. We take for the SC as the carrier of TTBF. In order to make the SC as effective carrier of TTBF, an intelligent nutrient management system or intelligent compound system that consists of a set of SC should be produced according to authors' study (Fan, 2001).

Although manufacturing and applying specialty compounds are a trend and SC is composed of 80% of compounds in advanced nations (Fu, 1997; Hu, 1999), the SC consisted of only 10% of total chemical fertilizer in 1997 and expected 30% in 2000 in China (Fu, 1997). According to literature of fertilizer and fertilization last decade in China, Chinese scientists started to discuss SC in 1980's (Xi, 1987). However, there are no more than 300 papers relating SC among 5434 ones in relation to fertilizer since 1994 according to China Journal net (CNKI). The investigation results inform us that research on SC is not systematic in China yet. Nevertheless, there are more than decades SC including winter wheat, corn, rice, rap seed, cotton, beet, peanut, soybean, potato, tomato, long-bean, eggplant, apple, tea tree, banana, strawberry, watermelon, tobacco, ornament plant and so on among the 300 papers in literature (Tang, 1993; Yan, 1994; Zhu, 1994; Yao, 1994, Ma, 1998, Zhang, 1995; Xong, 1996; Cai, 1997). To produce so many kinds of specialty compounds is benefit to develop compound industry, whereas it may not good for promoting and popularizing TTBF for following reasons.

1. If the fertilizer enterprises produce SC for every plant and each region, the plant will face great pressure of so many raw materials and package. Consequently manufacturing SC will limit production i.e. production scope being limited and the plant will lost benefits from large-scale production.
2. Tinpot compound or low quality compound may be a side effect and then SC will lose the function of TTBF carrier while developing so many kinds of SC. In addition, the more SC products put into market, the more agro-chemistry service is required. However, manufactures, vendors or distributors and farmers lack knowledge of plant nutrition and fertilization as well as soil science at present in China. Therefore, even if some small enterprises do not want to make fake products, their products may encourage fake one caused by imitation. In certain instances some law-breaker may make fake products on purpose to obtain sudden huge profits.
3. Consumers or farmers will face great difficulties to choose right compound among the huge number of SC. In other word, it is difficult to put TTBF into effect because the choice of fertilizer by farmers is to depend on distributors' recommendation. As discussed above, not only because distributors are poor in professional knowledge, but also they pay more attention to the most profitable SC, the compound recommended by distributors in most cases is not fit to demand of farmers' crop but the one they will get most profit.
4. The current SC is not special for target crops because present SC is designed for a given crop with a fixed NPK ratio or formula. The reason will be discussed in next section.

Connotation and establishment of intelligent compounds system

Connotation of the intelligent compounds system

The intelligent compound system is the achievement of projects supported by the natural science foundation of China, key teacher project of Chinese education ministry, natural science foundation of Guangdong province and KEMIRA Agro Oy. The system is composed of a sire of technique to produce and apply SC to realize materializing TTBF and to extend it in agriculture as soon as possible. Theory and technology of balanced fertilization, being achievement of old generation of Chinese scientists' study over last 20 more years, is the foundation of the system.

The compounds in the intelligent system are designed according to crop nutrition characteristics of different growing stage. Accordingly, the intelligent compound system consists of three different formula NPK compounds (SC1, SC2 and SC3 as above) for fruit trees and fruit vegetables such as litchi, longan, banana, mango, hot pepper and tomato (unpublished results). They are applied in three different growing stages of the plants to fit NPK demand in each stage to increase fertilizer use efficiency. The compounds are also specialty ones because each compound is only suitable for a certain growth stage. In addition to its specialty, this set of compounds is universal because not only the compounds suitable for most fruit trees, but also each of the compounds fits to the nutrient requirement of a kind of crop, such as SC1 for winter wheat, corn, leave vegetables' growth. Therefore, the set compounds are termed intelligent compound (IC) and this nutrient management system termed intelligent nutrient system (INMS). By use of the system, production of chemical fertilizer will be simplified because the plant needs only to produce three kinds of compounds rather than decades. The manufacturer will decline production costs and obtain benefits from lower investment, higher quality, and larger scale production. On the other hand, farmers will also obtain benefit from high quality, suitable fertilizer and simplifying technique of fertilization. The distributor may also get benefits by winning reputation and name of professional distributor by selling high quality products that will ensure his sales.

Principle of the intelligent compound system

According to plant nutrition, NPK demand of a plant is different from each other because genotype difference. Current specialty compound is then designed according to nutrients demand of every kind crop (Duan, 1995; Cai, 1997; Chen, 1999; Hu, 1999; Zhang, 1999). Therefore, the so called specialty compound is not special or not suitable for crop requirement of whole life because almost all kind of specialty compounds is produced according to a life nutrients requirement of a given plant in a given region. Although NPK amount may be suitable for whole life demand in average, but it does not fit nutrient requirement of each growing stage. The principle of establishing intelligent compound system is to develop three compounds to fit nutrient requirement of the three growing stages for a class of fruit trees having similar life cycle. For example litchi, longan, mango, apple, peach and pear have the similar fruiting life cycle that is divided into three main growing stages shown in Figure 2. Each stage has its own nutrition characteristics and requires a specialty compound to fit the requirement and to ensure the maximum growth of the plant. Integration of the three compounds applied for each growth stage will form the intelligent compound system. Then the theory and technology of balanced fertilization is materialized into the set of compounds. In other word the intelligent compounds system makes the TTBF be materialized into fertilizer rather than a concept only. Therefore, the theory and technology of balanced fertilization is simplified and easily mastered and applied by farmers.

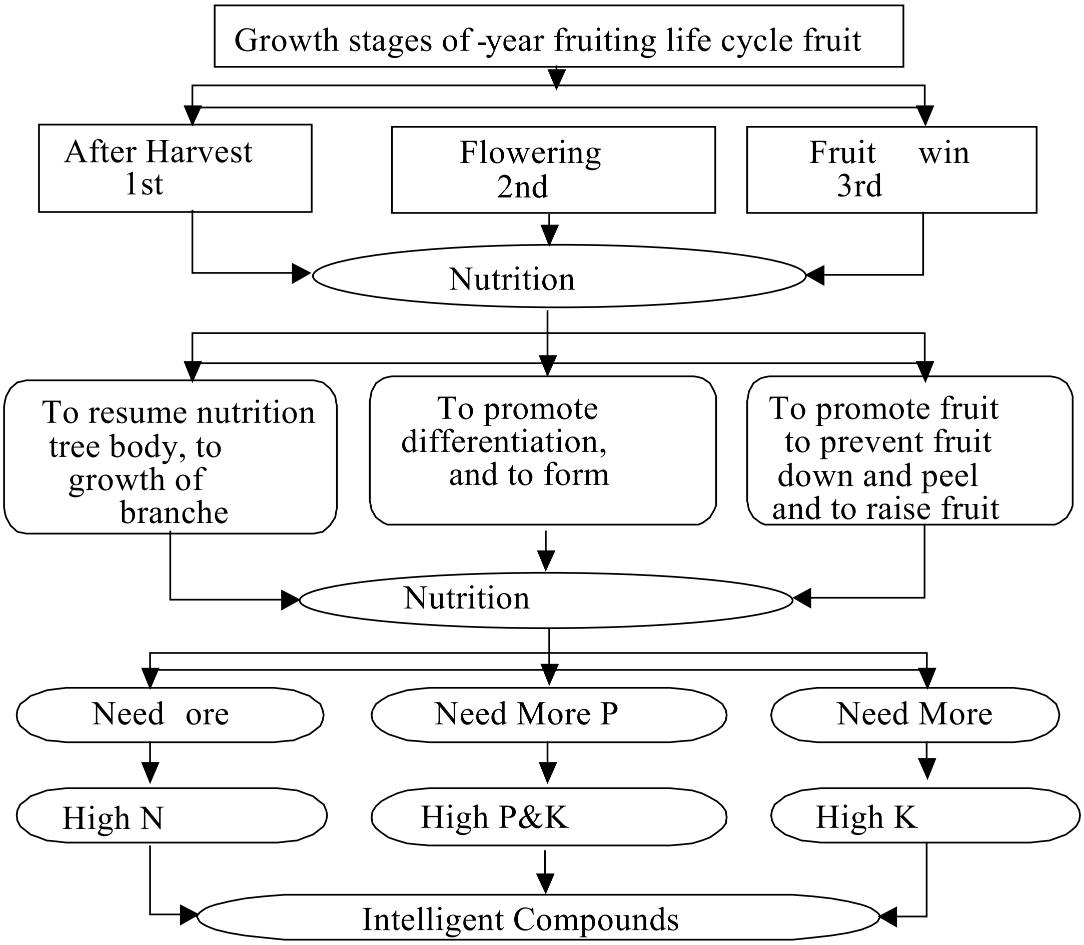

Figure 2 Principles and establishment of Intelligent Compounds System for litchi as an example.

Intelligent compounds and its effectiveness

Since 1999 with the support of both NSFC and Kemira Agro Oy, a set of intelligent compounds that is composed of high N formula NPK (SC1), high phosphorus and potassium formula compound (SC2) and high potassium formula compound (SC3) has been approved to be suitable for litchi and fruit vegetables through both pot experiment and field trials. Results showed that intelligent compound system was able to increase litchi and fruit vegetables' yield, and chemical quality (Tables 1 and 2). Also, fruit splitting rate and disease spots are decreased (Figure 3) and hot pepper fruit number and size are increased (Figure 4).

Results in Table 1 indicated that litchi yield of 8 years old orchards treated with IC was increased from 17% to 37% compared to local treatment with the same NPK. It was 19% to 40% of 5 years old orchards (Table 1). Litchi yield of the IC treatment was significantly higher than local one even if total amount of IC is half of local treatment. The reason why the IC resulted high yield is that NPK formula of each compound is suitable for litchi growth in each of the main growing stage. The interesting thing is that although farmers have been used to apply imported triple 15 compounds (Superstar 15-15-15) combined with super-phosphate for last 10 more years, their hot pepper yield was increased 21% by just transferring their habit of using only Superstar 15-15-15 into the IC compounds (SC1, SC2 and SC3).

Table 1 Effect of intelligent compounds (IC) on yield and sugar content of litchi.

Trial site	Fertilization rate (kg/tree)	Yield per tree (kg)	Yield increasing rate (%)
Maoming	Intelligent compounds 6	18.71 a	37.66
	Intelligent compounds 2	15.95 ab	17.38
	Intelligent compounds 4	17.23 a	26.79
	Local compounds 4	13.59 b	
Zengcheng	Intelligent compounds 6	6.93 ab	19.53
	Intelligent compounds 2	8.16 a	40.60
	Intelligent compounds 4	8.03 a	38.36
	Local compounds 4	5.80 b	

* Numbers in the same column with different letters indicate significantly different at P<0.05 respectively, Duncan's multiple range test.

Table 2 Effect of intelligent compounds (IC) on yield (kg ha^{-1})of hot pepper.

Treatments	Yield	Yield increasing rate (%)
Intelligent compounds	38.88 ***	21.2
Check 15-15-15	32.09 ***	

Note: Data in the table is from Leizhou agricultural bureau based on hot pepper experiments from 2000 November to 2001 January. *** Indicates significant difference at 1% level.

Figure 3 Effect of intelligent compounds on quality of litchi fruit.

38.88 t ha^{-1} 32.09 t ha^{-1}

Figure 4 Comparison of hot pepper growth in intelligent compounds (left) and traditional compounds (right) system (2001).

CRF and balanced fertilization in relation to sustainable agriculture

Controlled release fertilizer (CRF) is the final way to realize materialization of TTBF into fertilizer to increase fertilizer use efficiency (FUE) and simplify fertilization technique (Deng, 2000, 2001; Fan, 2001). Therefore, a multiple coating urea (MCU) was developed as a kind of controlled release fertilizer (CRF) for rice and the other cereal crops during the course of intelligent compound system research. The principle and structure of the MCU is shown in Figure 5. The target of simplifying fertilization method is to use one-off application method (OAM) to instead of splitting one and keep the same or higher FUE. Two years results show that 2:1:1 is the suitable NPK formula for rice and winter wheat growth with OAM. Results of rice and winter wheat indicated that OAM of MCU would not only result in higher yield, high NUE, but also application OAM would save manpower compared with the other slow release fertilizers (Gypsum urea) and same amount of mono-element chemical fertilizer mixed as BB fertilizer before fertilization (Tables 3 and 4).

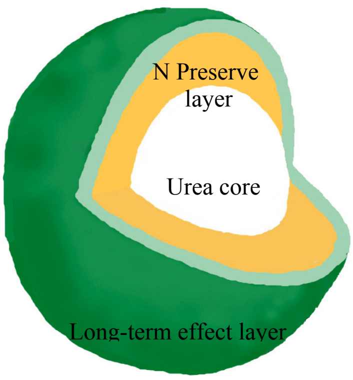

Figure 4 Structure of multiple coating urea as controlled release fertilizer.

Table 3 Effect of MCU as CRF on rice yield (t ha^{-1})and NUE*.

Treatments	Measured			Yield increasing rate compared with normal urea (%)		
	Yield	NfUE (%)	NUpE (%)	Yield	NfUE (%)	NUpE (%)
Control (no N)	6.62 c		41.34			
BB treatment	7.13 b	11.62	52.93			
MCU 100% base as OAM	8.31 a	16.31	57.63	16.50	40.36	8.88
G-urea Splitting	8.74 a	22.98	64.32	22.55	97.76	21.52
G-urea 100% base as OAM	7.36 b	7.92	49.24	3.2	-31.84	-6.97

* Numbers in the same column with different letters indicate significantly different at $P < 0.05$ respectively, Duncan's test

Table 4 Effect of MCU as CRF on winter wheat yield (t ha^{-1}) since1999 to 2000*.

Item	Treatment	Field experiment site		
		1	2	3
Yield Y (ton ha^{-1})	CRF (MCU)	8.60 a	6.11 a	6.60 a
	BB treatment	7.50 b	5.57 b	6.05 b
	Local average (LA)	4.88 c	4.88 c	4.95 c
Y increasing compared to LA (%)	CRF (MCU)	76.4	25.4	33.3
	BB treat	53.8	14.3	22.2
Y increasing compared to BB (%)	CRF (MCU)	14.6	9.7	9.1

* Numbers in the same column with different letters indicate significantly different at $P< 0.05$ respectively, Duncan's test

Results of rice and winter wheat showed that although nitrogen resource was the same as urea for both BB treatment and CRF and they are used at the same time with the same amount and same methods, rice yield increased 16.5% and winter wheat yield increased from 9.1% to 14.6% in two years field trials. The reason why the yield increased significantly is that urea is coated by N preserve materials as the first coating layer and then coated by partially waterproof and pressure proof materials as long term effect layer, being outer layer to form MCU as CRF (Figure 4). The 1st layer is capable of MCU to store more N released from urea and the outer layer ensure the stored N stay a longer time in the fertilizer particles. Therefore, N nutrient is able to supply to plant gradually and more N will be consumed by crops rather than lost compared with normal urea. N fertilizer use efficient (NfUE) of MCU was increased 40.36% compared to normal urea as BB fertilizer during rice growth (Table 3). The dynamic parameters indicated that velocity coefficient k of normal urea was about 23% more than that of MCU as CRF (Table 5).

Winter wheat results indicated that intelligent compound system is much more favorable than farmers' practice in two aspects. Comparing with BB treatment (farmers habit) yield in treatment of IC increased from 9.1% to 14.6% at the same amount of NPK. Comparing with local average (LA), although N input in CRF treatment was 21.2% more than LA, yield of MCU was 45% more than LA in average (Table 4).

Results also indicated that potassium is very important in winter wheat production in Shaanxi province (Table 4). In addition to CRF, slow release fertilizer (G-urea) combined with proper method (splitting method) resulted in the highest yield and NfUE. It can be concluded that both CRF or slow release fertilizer and theory and technology of balanced fertilization will ensure high yield and efficiency.

Table 5 The theoretical greatest amount of nitrogen supplying (N_o), the first-order equations and their correlation coefficients (r) and standard errors (SE) of different treatments.

Treatments	No (mg kg^{-1})	Ln (No- N_t) = ln No - kt	*SE*	*R*
MCU (CRF)	1204	Ln (1204 - N_t) = 3.0806 - 0.3148 t	36.12	-0.9993 **
Normal Urea	1400	Ln (1400 - N_t) = 3.1461 - 0.3865 t	48.28	-0.9997 **

**Indicates significant difference at 1% level.

Conclusion

In conclusion, factors limiting fertilizer use efficiency are gap between theory and technology of balanced fertilization and farming practice and gap between production and demand at present in China. In other word, achievement of theory and technology of balanced fertilization (TTBF) has not been mastered by farmers and put into farming practice because of lacking such a qualified compound which is not only convenient for farmers' use, but also is carrier of theory and technology of balanced fertilization in China.

In order to increase fertilizer use efficiency, it is suggested that chemical compound plant should treat itself as TTBF master and produce intelligent compounds to realize intelligent nutrient management system.

The compounds in the intelligent nutrient management system are not only a series of specialty ones, but also are characterized by universal use for the other crops. Therefore, this intelligent compounds system will be capable of materializing TTBF without increasing production cost, but also able to standardize technique of compounds production and to simplify fertilization technique.

By use of the intelligent compounds and the nutrient management system litchi yield increased from 17% to 37% and 19% to 40% for 8 and 5 years old orchards respectively. Hot pepper yield raised 21%. Rice yield and NUE increased 16% and 40% separately. Winter wheat yield in MCU treatment was about 9% to 17% over the traditional fertilization methods, and then about 25% to76% over the local treatment. Velocity to supply N, being velocity constant (0.3865) of normal urea was about 22% faster than that of multiple coating urea (0.3148).

Outlook

It is well known that agriculture is the base of the national economy in China and chemical fertilizer is one of the biggest essential production materials in agriculture. Fertilizer plays an important role in increasing crop production. However, it is also costly according to Lin's report (1999). Although China imported 80 to 100 MT of chemical fertilizer to meet the demand of agricultural production, chemical fertilizer shortage is estimated about 10 MT until 2030. However, this costly input material has not been used most efficiently. Under the circumstances of taking part in the WTO and specialty compounds starting to be more popular in China, along with effort to increase fertilizer production and importation for adequate supply, great attention is needed to improve fertilizer use efficiency and to minimize or prevent negative influent of fertilizer use on environment. Emphasis should be given to following aspects in relation to fertilizer.

1. Increasing total supply and adjust fertilizer structure to provide more reliable fertilizer. More reliable fertilizer is not only cheap, but also nutrient supply will fit the demand of crops. Fertilizer types or structures should fit the nutrient characteristics of each growing stage of plant. Establishment of intelligent compound system is currently the effective measure to ensure fertilizer factory to increase production and to produce high quality compounds to extend the theory and technology of balanced fertilizer to make the compounds meet the nutrient demand of crops.

2. Improve fertilizer use efficiency. Theory and technology of balanced fertilization should be extended and applied by farmers as soon as possible. At present, the proper way to popularize the theory and technology is that enterprises of chemical fertilizer production should act as master materializing the theory and technology, and the fertilizer itself as carrier of the theory and technology rather than nutrients only. The intelligent compound system designed according to nutrition characteristics of a kind of plant discussed above is materialization of the theory and technology. It is easier and effective for farmers to master and use the theory and technology of balanced fertilization, and then the theory will be extended faster and broader. Introducing specialty compound to farmers is then an effective way and a shortcut to extend balance fertilization to increase fertilizer use efficiency in China.

3. In addition to economy efficiency, manufacturer distributor should consider the series of specialty compounds rather than only one. Farmers should be informed the intelligent compound system and the intelligent compounds are not only proof products but also they are materialization of TTBF. If farmers accept the fertilizer, they will fertilize their crops scientifically and simply. The only way for reciprocity and mutually beneficial among enterprises, distributor and farmers is to supply agro-chemistry service to farmers.

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