Controlled-Release Urea in Banana Production in Southern China

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Researchers tested complete or partial substitution of controlled-release urea for regular urea in order to identify new options capable of offering high fruit yield along with improved efficiencies in crop management and N use.

Banana is widely grown in southern China where the crop covers 400,000 ha and annual fruit production has reached 12 million t (MOA, 2013).

Banana requires much larger quantities of nutrients (especially N and K) than other common field crops due to the crop's obviously large biomass. In order to improve N use efficiency during the rainy, summer season, growers often have to divide their N fertilizer into six to eight applications to minimize ammonium volatilization, nitrate leaching, and denitrification. Since manual fertilizer application are still common in China's plantations, these split applications have created difficult, time consuming, and costly work in the hot, humid, and sometimes wet fields.

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium. IPNI Project CHN-GX15

Controlled-release urea (CRU) is considered to be an N source capable of delivering enhanced efficiency in crop production. Use of CRU has reduced the number of split applications of N fertilizer while still improving crop yield and crop N uptake (Haderlein et al., 2001; Geng et al., 2015). These characteristics make CRU an ideal N source for banana.

The objectives of this study were to examine the optimal rates and timing of CRU manufactured by Agrium Inc. (Calgary, Alberta, Canada) and to evaluate its influence on banana yield and quality. Researchers wanted to offer science-based information for proper CRU use. This three-year (2013 to 2015) field experiment compared different rates, timings, and blends of CRU and regular urea (RU) (**Table 1**). The full rate of N

Table 1. Controlled-release urea (CRU) and regular urea (RU) rates and application timings tested with banana, Guangxi, China.

Treatment	N rate, kg/ha Total	CRU	RU	Timing of application Basal	Side-dressings
No N (CK)	0	0	0	0	0
RU (5)[1]	673	0	673	1	5
CRU (1)	673	673	0	1	1
CRU (2)	673	673	0	1	2
CRU+RU (80:20) (1)	673	538	135	1	1
CRU+RU (80:20) (2)	673	538	135	1	2
CRU @ 80% N rate (1)	538	538	0	1	1
CRU @ 70% N rate (1)	471	471	0	1	1
CRU+RU (60:40) @ 80% N rate (1)	538	323	215	1	1

[1]Figures in the brackets refer to the number of side-dressings.
Rates for P and K were 176 kg P_2O_5/ha (as fused Ca-Mg phosphate) and 878 kg K_2O/ha (as potassium chloride), which were split three times between basal, flower bud initiation, and the fruit swelling stages.

Table 2. Effects of different controlled-release urea (CRU) and regular urea (RU) combinations on banana yields in 2013 to 2015, Guangxi, China.

	---- 2013 ----		---- 2014 ----		---- 2015 ----	
Treatment	Yield, t/ha	±% vs. RU	Yield, t/ha	±% vs. RU	Yield, t/ha	±% vs. RU
No N (CK)	16.2 c[2]	-48	24.5 c	-36	18.9 d	-61
RU (5)[1]	31.0 ab	-	38.4 b	-	48.1 b	-
CRU (1)	33.2 a	7.0	40.9 a	6.6	50.5 ab	5.0
CRU (2)	34.0 a	9.8	41.0 a	6.8	52.1 a	8.2
CRU+RU (80:20) (1)	30.6 b	-1.4	39.1 ab	1.9	48.7 b	1.2
CRU+RU (80:20) (2)	30.8 b	-0.7	39.4 ab	2.8	50.6 ab	5.1
CRU @ 80% N rate (1)	31.3 ab	0.9	38.7 b	1.0	47.7 b	-0.8
CRU @ 70% N rate (1)	30.8 b	-0.9	38.2 b	-0.5	45.5 c	-5.4
CRU+RU (60:40) @ 80% N rate (1)	30.3 b	-2.3	39.3 ab	2.4	48.5 b	0.8

[1]Figures in the brackets refer to the number of side-dressings.
[2]Values in each column followed by different letters are statistically different at p=0.05.

applied as RU was split six times between a basal application, three seedling side-dressings, flower bud differentiation, and fruit swelling. The CRU was applied basally and the remainder was either side-dressed solely at the seedling stage, or was split between the seedling and fruit swelling stages. Prior to the flower bud shooting stage, all fertilizers were broadcast and incorporated into the soil around the drip line of the banana canopy. The banana seedlings were transplanted in the first year and the suckers (daughter plants) sprouted from the previous plant corms that were used as the second and third crops.

Yield Responses

Banana yields varied considerably from year to year, but trends showed an increase with time. Importantly, CRU increased banana yield while reducing the number of split applications of N (**Table 2**). The two full rate CRU treatments consistently produced the highest yields. Dividing CRU into two side-dressings improved yield marginally compared to the single side-dressing, but with no economic advantage (**Table 3**). In the first two years, CRU applied at 80% of the full N rate produced higher yields than the full rate of RU, but this trend ended during year 3. CRU applied at 70% of the full N rate consistently produced lower yields and this yield gap increased with time. Blended CRU+RU (80:20) produced slightly lower yields than RU in year 1, but this reversed in the last two years, especially for the treatment with two side-dressings. Similar results were observed for the reduced rate (80%) CRU+RU blend, which also implies a feasible practice at this location.

Banana yields were not significantly related to agronomic traits such as plant height, stem girth, or flower bud shooting date, but they were related to finger number per plant and finger weight (data not shown). The study found that adequate finger number per plant, and bigger fingers, were key to obtaining high yields. This observation agrees with other research that reports on CRU's benefits on yield components such as increased kernel/ear and 100-kernel weight for maize (Wang et al. 2011), increased boll number per plant and boll weight for cotton (Hu et al., 2011), and increased effective tillers, filled grain per panicle, and 1000-grain weight in rice (Yang et al., 2013).

Economic Returns and Agronomic Efficiency

For net returns, all CRU options generated more income than the RU treatment (**Table 3**). Among the CRU options, the two full N rate treatments proved most profitable.

Besides the potential for CRU to improve yield and profits with reduced labor, based on the large N input that is associated with banana crop production, the anticipated environmental gains related to CRU are large. Researchers report that CRU can reduce

Table 3. Economic returns as affected by combinations of controlled-release urea (CRU) and regular urea (RU), Guangxi, China.

	2013	2014	2015
Treatment	---- Net income[2], US$/ha ----		
No N (CK)	5,690	10,020	5,520
RU (5)[1]	11,400	15,240	15,600
CRU (1)	13,100	17,120	17,200
CRU (2)	13,300	16,940	17,590
CRU+RU (80:20) (1)	11,880	16,290	16,530
CRU+RU (80:20) (2)	11,760	16,060	17,050
CRU @ 80% N rate (1)	12,320	16,210	16,220
CRU @ 70% N rate (1)	12,120	16,000	15,410
CRU+RU (60:40) @ 80% N rate (1)	11,920	16,570	16,630

[1]Figures in the brackets refer to the number of side-dressings.
[2]Net income refers to the values after deducting the total cost including fertilizers (CRU prices have exceeded regular urea by US$154 to US$200/t), pesticides, labor, irrigation, and harvest.

N losses via ammonium volatilization by 51 to 71% in winter wheat (Lu and Song, 2011) and by 51 to 91% in summer maize (Zhao et al., 2009). In rice, N loss reductions of 24 to 27% through runoff were measured in paddy fields by Ji et al. (2007), and Xie et al. (2016) found 28 to 55% less N_2O emissions in maize.

In this study, agronomic efficiency (AE) from CRU, used alone, at a reduced rate, or in combination with RU, was higher than with RU alone (**Table 4**). The CRU options providing reduced N rates had the highest AE values for three consecutive years, which were followed by the two CRU treatments providing the full N rate.

Table 4. Agronomic efficiency (AE) of nitrogen as affected by combinations of controlled-release urea (CRU) and regular urea (RU), Guangxi, China.

	AE[2] in 2013		AE in 2014		AE in 2015	
Treatment	kg/kg	±% vs RU	kg/kg	±% vs RU	kg/kg	±% vs RU
RU (5)[1]	22.0	-	21.1	-	43.4	-
CRU (1)	25.3	15	24.9	18	47.0	8
CRU (2)	26.5	20	25.0	18	49.3	14
CRU+RU (80:20) (1)	21.4	-3	22.2	5	44.2	2
CRU+RU (80:20) (2)	21.7	-1	22.7	8	47.0	8
CRU @ 80% N rate (2)	28.1	28	27.1	28	53.5	23
CRU @ 70% N rate (1)	30.9	40	29.7	41	56.5	30
CRU+RU (60:40) @ 80% N rate (1)	26.2	19	28.1	33	55.0	27

[1]Figures in the brackets refer to the number of side-dressings.
[2]Agronomic efficiency = kg grain yield increase/kg applied N.

Summary

Controlled-release urea significantly reduced the number of fertilizer N applications from a 6-split strategy with regular urea to a less demanding and less costly 2 to 3 splits with CRU. Banana yields with CRU were generally 5 to 10% higher compared to RU. The higher yields were attributed to improved finger number per plant and finger weight. The full CRU-N rates proved best, followed by CRU applied at a reduced (80%) N rate. However, reduced N rate options could only maintain two to three years of high yield production given the site's soil fertility status. Agronomic efficiency of N was the highest for both reduced rate (70% and 80%) CRU options, followed by either CRU treatment applied at the full N rate. CRU alone achieved the best returns, but CRU applied in blends with urea, or in reduced rates, were all feasible practices. BC

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References

Geng, J.B., Y.B. Sun, M. Zhang, C.L. Li, Y.C. Yang, Z.G. Liu, and S.L. Li. 2015. Field Crops Res. 184:65-73.

Haderlein, L., T.L. Jensen, R.E. Dowbenko, and A.D. Blaylock. 2001. The Sci. World 1(S2):114-121.

Hu, W., Y. Zhang, G.Z. Hu, Q.J. Li, and M.Y. Tang. 2011. Cotton Sci. 23:253-258.

Ji, H.H., S.X. Zheng, Y.H. Lu, and Y.L. Liao. 2007. Chinese J. Applied Ecol. 18:1432-1440.

Lu, Y.Y. and F.P. Song. 2011. Acta Ecol. 31:7133-7140.

MOA. 2013. China Ag. pp. 225-227.

Wang, Y.J., Q.Z. Sun, J.S. Yang, K.J. Wang, S.T. Dong, C.P. Yuan, and L.C. Wang. 2011. Acta Agron. 37:2233-2240.

Xie, Y., X.M. Rong, Y.P. Zhang, X. He, D.J. Shi, and Q. Liu. 2016. J. Agro-Envir. Sci. 35:596-603.

Yang, C.L., L. Yuan, Y.C. Li, X.Q. Liang, L.H. Wu, and H.K. Chen. 2013. Chinese J. Soil Sci.44:184-190.

Zhao, B., S.T. Dong, K.J. Wang, J.W. Zhang, and P. Liu. 2009. Chinese J. Applied Ecol. 20:2678-2684.