Response of Potato to Fertilizer Application and Nutrient Use Efficiency in Inner Mongolia

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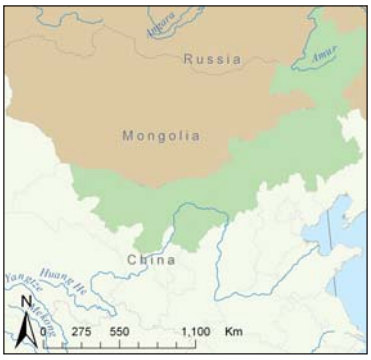
Potato production in Inner Mongolia is limited by unbalanced nutrition and inadequate water supplies. Field trials find balanced fertilization can significantly increase tuber yield for both rainfed and irrigated potato. Crop uptake of N, P and K increased rapidly at 25 to 57 days after emergence (DAE) under both rainfed and irrigated conditions. The economic benefit from fertilizer application was higher in irrigated versus rainfed potato.



The Inner Mongolia Autonomous Region (IMAR) is one of the major potato production areas in China with a potato planting of about 760,000 ha and a total production of 9.55 million t. However, potato yields in the region are restricted both by water shortage and by unbalanced fertilizer application. Understanding the response of potato to fertilizer application and NUE are important for efficient nutrient management and high potato yields in the IMAR.

From 2002 to 2011, field trials were conducted on rainfed and irrigated potato across Inner Mongolia. Some chemical properties of the experimental soils are listed in **Table 1**. All the trials had four treatments including a balanced fertilization or OPT treatment, which was determined by soil analysis using the ASI procedure (Portch and Hunter, 2005; Bai et al., 2007), and three nutrient omission plots (i.e., OPT-N, OPT-P, OPT-K). The recommended rates for rainfed potato were 45-150 kg N/ha, 30-60 kg P_2O_5/ha, and 30-90 kg K_2O/ha with a mean of 83-44-50 kg N-P_2O_5-K_2O/ha; while rates in irrigated potato were 120-300 kg N/ha, 60-150 kg P_2O_5/ha, and 90-225 kg K_2O/ha with a mean of 190-97-137 kg N-P_2O_5-K_2O/ha (**Table 2**).

Table 1. Selected chemical properties of experimental soils, Inner Mongolia.

Year	County	Water regime	pH	OM, %	Mineral N, mg/l	Olsen P, mg/l	Exchangeable K, mg/l
2002	WUC*	Rainfed	7.8	0.8	13	15	66
2003	WUC	Rainfed	8.6	1.2	13	13	77
2004	WUC	Rainfed	8.4	1.0	75	14	70
2004	WUC	Rainfed	8.5	1.0	48	18	78
2005	WUC	Rainfed	8.2	1.3	32	12	55
2006	WUC	Rainfed	7.8	1.0	8	16	145
2007	WUC	Rainfed	8.3	0.9	35	14	68
2007	WUC	Rainfed	8.4	1.0	75	14	70
2008	WUC	Rainfed	8.5	0.8	27	11	62
2011	WUC	Rainfed	8.3	1.0	20	19	89
2002	WUC	Flood Irrigation	8.3	0.7	9	15	76
2003	WUC	Flood Irrigation	8.4	1.1	10	18	83
2004	WUC	Flood Irrigation	8.4	1.2	8	10	55
2005	WUC	Flood Irrigation	8.4	1.4	30	10	66
2006	CHYZ**	Flood Irrigation	7.9	0.4	8	21	59
2007	CHYZ	Flood Irrigation	8.4	1.4	41	25	109
2008	WUC	Flood Irrigation	8.5	1.3	24	19	124
2008	WUC	Flood Irrigation	8.7	0.7	33	6	79
2008	CHYZ	Sprinkler Irrigation	8.9	0.3	51	12	99
2009	CHYZ	Flood Irrigation	8.4	1.3	19	27	137
2009	WUC	Flood Irrigation	8.5	2.5	24	8	138
2009	WUC	Sprinkler Irrigation	8.5	1.3	43	38	90
2010	WUC	Flood Irrigation	8.4	0.8	34	20	81
2010	WUC	Sprinkler Irrigation	8.4	0.4	26	14	54
2011	WUC	Drip Irrigation	8.1	1.3	20	14	80
MAX			8.9	2.5	75	38	145
MIN			7.8	0.3	8	6	54
MEAN			8.4	1.0	29	16	84

*WUC = Wuchuan County; **CHYZ = ChaYouZhong County.

Yield Response and Nutrient Use Efficiency

Rainfed Sites

Ten experiments with rainfed potato produced tuber yields between 9.6 to 21.4 t/ha (14.9 t/ha average) with OPT treatments (**Table 2**). An average of 3.2 t/ha (27%), 2.4 t/ha (22%), and 2.2 t/ha (19%) more tuber was produced in balanced OPT plots than in N, P and K omission plots, respectively. Potato gave significant responses to N, P and K applications in 8, 9 and 8 of the 10 site-years, respectively. The average agronomic efficiencies (AE) of N, P and K were 41 kg tuber/kg N, 55 kg tuber/kg P_2O_5, and 43.2 kg tuber/kg K_2O. The average recovery efficiencies (RE) of N, P and K fertilizers were 33, 17 and 50%, respectively. An average of 5.89 kg N, 1.44 kg P_2O_5, and 5.52 kg K_2O was required to produce 1 t of tuber at the 14.9 t/ha yield level.

Irrigated Sites

Fifteen experiments with irrigated potato found OPT treatments able to increase tuber yields over N, P and K omission treatments by an average of 7.1 t/ha (26%), 6.5 t/ha (23%), and 5.8 t/ha (20%), respectively (**Table 2**). Significant responses to N, P and K fertilizer application were noted in 15, 12 and 10 of the 15 site-years. Thus N was the most limiting nutrient for the region's area under irrigated potato followed by P, then K. The average AE for N, P and K was 37.9 kg tuber/kg N, 65.6 kg tuber/kg P_2O_5, and 41.1 kg tuber/kg K_2O. The average RE for N, P

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; NUE = nutrient use efficiency.

Table 2. Yield response to fertilizer application and NUE in rainfed and irrigated potato, Inner Mongolia.

Year	Nutrient applied, kg/ha			Tuber yields, t/ha				AE, kg/kg			RE, %			Nutrient requirement, kg/t		
	N	P_2O_5	K_2O	OPT*	OPT-N	OPT-P	OPT-K	N	P_2O5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Rainfed																
MAX	150	60	90.0	21.4	15.7	17.3	18.5	90.3	117	62.0	51.3	21.2	92.6	7.36	2.35	7.71
MIN	45	30	30.0	9.60	7.50	5.90	7.30	9.30	21.1	26.7	22.3	13.1	23.6	4.09	1.02	3.36
MEAN	82.8	43.5	49.5	14.9	11.7	12.5	12.6	41.0	55.0	43.2	33.1	16.8	50.1	5.89	1.44	5.52
Irrigated																
MAX	300	150	225	60.2	47.8	44.2	47.2	70.3	133.3	93.7	50.4	20.6	65.4	9.05	2.51	9.44
MIN	120	60	90	12.9	9.90	10.2	10.1	20.0	13.3	8.60	28.5	9.20	38.3	4.04	0.94	4.38
MEAN	190.1	97.1	137.0	35.7	28.6	29.2	29.9	37.9	65.6	41.1	35.6	14.9	49.9	5.56	1.48	6.21

*OPT = balanced fertilization treatment determined by soil testing based recommendation of ASI procedures (Portch and Hunter, 2005; Bai et al., 2007).

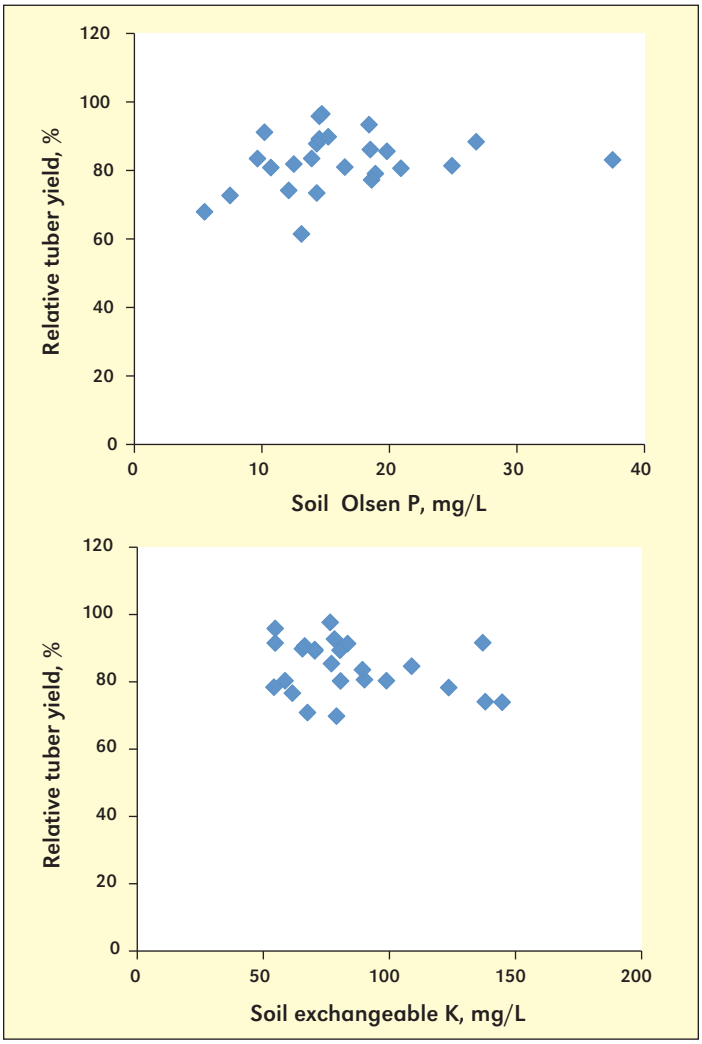


Figure 1. Relationship between the relative yield of potato tuber in OPT-P and OPT-K plots (i.e., the ratio of tuber yield in OPT-P or OPT-K plot to the tuber yield in the OPT plot) with available soil P (top) and exchangeable soil K (bottom) for 25 site-years.

and K fertilizers were 36, 15 and 50%. An average of 5.56 kg N, 1.48 kg P_2O_5, and 6.21 kg K_2O was required to produce 1 t of tuber at the 35.7 t/ha yield level.

It is clear that the recommended rates of nutrients for irrigated potato were 2.2 to 2.8 times that recommended for rainfed potato. Similarly, the tuber yield for irrigated potato was, on

Irrigated potato research site in Inner Mongolia.

average, 140% higher than the yield for rainfed potato. However, nutrient use efficiencies (AE and RE) were comparable between both systems. Similarly, mean N and P requirements to produce 1 t of tuber were similar for rainfed and irrigated potato, while more K was required under irrigated conditions.

Relationship between Relative Yields and Soil Test Values

No significant relationship existed between the relative yields of potato in OPT-P and OPT-K plots (i.e., the ratio of yield in either the OPT-P or OPT-K plot to the yield in the OPT plot) and soil test P and K values (**Figure 1**). For P, although most of the soil Olsen P was above the critical level of 12 mg/L, low temperatures (annual average temperature of 2.5°C) decreased P availability, especially at the seedling stage in the early spring, so additional P fertilizer was needed for crop production. For K, although 11 of the 25 experimental sites had exchangeable K above the critical value of 80 mg/L, applying K fertilizer still increased tuber yield. One reason could be the higher K requirement of potato plants, while another reason may be related with soil moisture conditions. Drying conditions may limit soil K availability, while in irrigated conditions more K is required by the potato plant to produce more tuber yield.

Nutrient Accumulation and Distribution

Nutrient accumulation was tested in different plant parts at different growth stages of rainfed and irrigated potato in 2011 in Wuchuan County. In irrigated potato, 85 to 100% of N, 76

to 100% of P, and 72 to 100% of K were accumulated in leaves and vines before 40 DAE (**Figure 2**). After 40 DAE, nutrient accumulations in tubers increased much above that in leaves and vines. About 71, 89 and 76% of the plant N, P and K, respectively, were accumulated in potato tubers at harvest.

In rainfed potato, most of N, P and K accumulation in the leaves and vines occurred before 25 DAE, thereafter nutrient accumulation in tubers increased rapidly (**Figure 2**). About 80, 91 and 91% of N, P and K, respectively, were accumulated in potato tubers at harvest. Greater portions of N and K were accumulated in rainfed tubers compared to irrigated tubers. There was a rapid uptake of N, P and K in the period between 25 to 57 DAE under both rainfed and irrigated conditions. This implies that N, P and K should be in sufficient supply before that period.

Table 3. Economic analysis of fertilizer application in rainfed and irrigated potato, Inner Mongolia.

	Gross income, $/ha				Net income, $/ha				Economic benefit, $/ha		
Year	OPT	OPT-N	OPT-P	OPT-K	OPT	OPT-N	OPT-P	OPT-K	N	P_2O_5	K_2O
					Rainfed						
MAX	3,424	2,512	2,768	2,960	2,080	1,304	1,463	1,742	1,453	649	744
MIN	1,536	1,200	944	1,168	250	-40	-314	-135	99	75	108
MEAN	2,384	1,872	2,000	2,016	1,087	640	727	762	447	360	325
					Irrigated						
MAX	9,632	7,648	7,072	7,552	6,890	5,127	4,399	4,905	1,906	2,491	1,985
MIN	2,064	1,584	1,632	1,616	1,259	355	309	567	470	127	61
MEAN	5,712	4,576	4,672	4,784	3,323	2,253	2,296	2,426	1,070	1,027	898

Prices: N: $0.75/kg, P_2O_5: $0.74/kg, K_2O: 0.70/kg, commercial potato: $0.16/kg.
Rainfed costs: seed potato and seeding: $632/ha, management including pesticide/herbicide: $169/ha, machine harvest: $363/ha. Irrigated costs: seed potato and seeding: $968/ha, management including pesticide/herbicide: $460/ha, irrigation: $242/ha, machine harvest: $726/ha.

Benefit from Fertilizer Application

Economic analysis showed that N, P and K fertilizer in rainfed potato increased farmer's income by US$99 to 1,453, $75 to 649, and $108 to 744/ha, with a mean of $447, $360 and $325/ha, respectively (**Table 3**). Application of N, P and K was more profitable in irrigated potato with respective increases of $470 to 1,906, $127 to 2,491, and $61 to 1,985/ha—averages of $1,070, $1,027 and $898/ha.

Conclusion

Potato tuber yields in both rainfed and irrigated conditions were significantly increased by balanced fertilization in Inner Mongolia. Potato required similar amounts of N and P in rainfed and irrigated conditions, but required more K under irrigated conditions. Sufficient nutrient supply is critical at 25 to 57 DAE. Application of N, P and K increased farmer's income significantly in both systems, but was more beneficial within irrigated systems. BC

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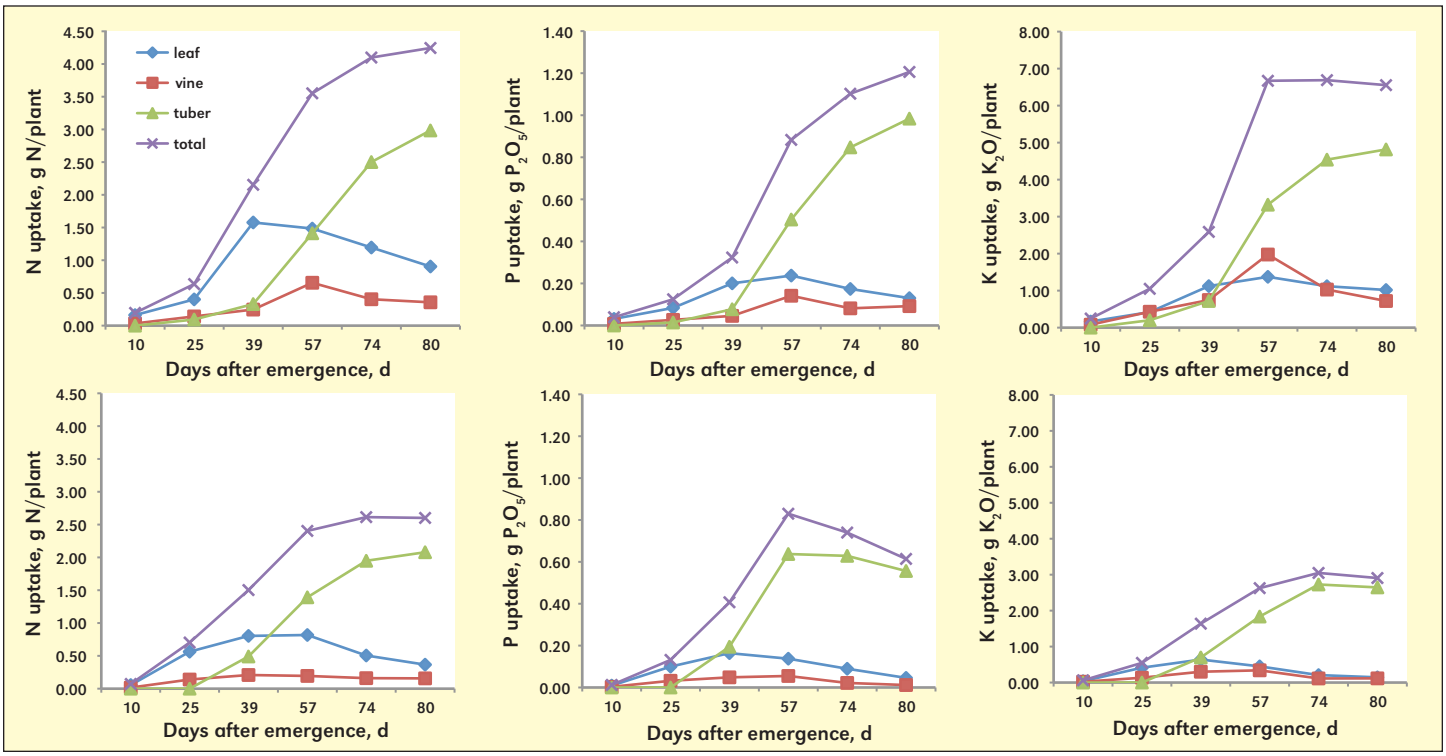

Figure 2. Accumulation of N, P and K by irrigated (top) and rainfed (bottom) potato in Inner Mongolia.