4R Nutrient Stewardship for Sunflower Crops in Northwest China

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Nutrient imbalance following over- and under-application of some nutrients has restricted sunflower production in Northwest China. A review of research demonstrates how the 4R Nutrient Stewardship approach can lead to better performing sunflower cropping systems.

Traditionally, fertilizer management within the 680,000 ha of sunflower grown in Inner Mongolia (IMAR) and the rest of northwest China has always focused on the application of any available manures along with N and/or P fertilizers. It is known that P fertilizers are commonly overused in the region, while less than 10% of sunflower ever receives K fertilizer (Tuo et al. 2010). Even in areas where K fertilizer is applied, the rates provide less than 30% of the crop's need. The research-based information below is organized according to the principle's of 4R Nutrient Stewardship …identifying the right sources of nutrients at right rates, time and place …in order to increase sunflower yields, farmer profits, and improve nutrient use efficiency within northwest China.

What is the Right Source?

Appropriate fertilizer sources for sunflower depend on soil nutrient status, irrigation method used, crop growth stage, and availability of organic nutrient sources. Sustained high yields in the IMAR region require balanced fertilization with a focus on soil-test-based S and Zn applications as well as Mn and B (**Table 1**). Low soil K availability commonly restricts plant growth and reduces sunflower yield and quality.

In a S-deficient soil, $(NH_4)_2SO_4$, SSP and K_2SO_4 may be the more appropriate fertilizer sources for N, P and K, because these sources will also supply S along with the intended nutrients. In fact, field study in IMAR shows that K_2SO_4 application can lead to higher profitability over KCl (**Table 2**). Jiang (2011) showed that applications of B and Zn increased seed yields of sunflower by 9.9 to 11% on soils low in these nutrients. Jabeen et al. (2013) indicated that foliar sprays of boric acid (H_3BO_3) and manganese chloride ($MnCl_2$) led to significant increases in seed number, seed weight, and oil content of seeds under non-saline or saline water irrigation practices. Yassen et al. (2011) studied the response of sunflower plants to two N fertilizers irrigated by agricultural drainage water and found that plant growth and yield increased by using NH_4NO_3 instead of $(NH_4)_2SO_4$.

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; S = sulfur; Zn = zinc; Mn = manganese; B = boron; SSP = single superphosphate; K_2SO_4 = potassium sulfate; KCl = potassium chloride; DAP = diammonium phosphate; MAP = monoammonium phosphate; NH_4NO_3 = ammonium nitrate; $(NH_4)_2SO_4$ = ammonium sulfate.

Sunflower covers almost 700,000 ha in northwest China, which represents over 70% of China's production.

Fertilizer efficiency can be improved by integration with organic sources as they improve soil physical properties and also supply a range of essential nutrients. Field studies by Reddy and Ahmed (2009) showed that the application of an organic sources along with 75% N from an inorganic source helped maintain good soil and plant nutrient statuses and also increased the yield and yield attributes of sunflower. Subha and Giri (2005) also indicated that the use of organics and bioresources could reduce the recommended rates of fertilizers by nearly 30%. Basal application or topdressing of highly soluble fertilizers such as urea, DAP or MAP, and KCl or K_2SO_4 can rapidly supply important nutrients to sunflower for use during rapid growth periods.

… the Right Rate?

Differences exist in N, P and K requirements of sunflower due to different varieties and locations. However, K is consistently needed in larger amounts than N or P. Generally, an average of 7.4 kg N, 1.9 kg P_2O_5 and 16.6 kg K_2O are needed to produce 100 kg seed of oil sunflower, while an average of 6.2 kg

Table 1. Some chemical properties of experimental soils in Inner Mongolia.

	pH	OM %	NH_4-N	NO_3-N	P	K	S	Fe	Cu	Mn	Zn	B
			mg/L									
Min	8.2	0.2	0.4	10.9	3.2	75.0	0.0	6.1	1.0	2.8	0.7	1.0
Max	9.1	2.0	35.8	80.2	40.2	149.0	176.8	18.8	78.9	14.5	2.5	12.5
Mean	8.6	0.5	10.1	24.9	22.8	100.2	36.8	12.4	15.5	8.9	1.6	3.7

*All parameters were analyzed using ASI procedure (Portch and Hunter, 2005).

Table 2. Effect of K source on sunflower yield and economics (IMAR, 2012).

Treatment	Seed yield, kg/ha	Yield increase over CK, %	Gross income, US$/ha	Fertilizer cost, US$/ha	Benefit from fertilizer, US$/ha	Benefit from K, US$/ha
CK	2,999c	-	3,869	0	-	-
-K	3,609b	20.3	4,656	225	562	-
KCl	3,945a	31.5	5,089	330	890	328
K_2SO_4	4,039a	34.7	5,210	378	964	402

*Fertilizer rates of N-P_2O_5-K_2O used were 225-75-135 kg/ha, respectively; prices used were: N = US$0.73/kg, P = US$0.81 P_2O_5/kg, K (KCl) = US$0.78 K_2O/kg; (K_2SO_4) = US$1.13 K_2O/kg, and sunflower seed = US$1.29/kg.

N, 1.3 kg P_2O_5 and 14.6 kg K_2O are required for producing 100 kg seed sunflower (Jiang, 2011).

IPNI research in the IMAR showed that the average N, P_2O_5 and K_2O uptake required to produce 100 kg seed (at an average yield level of 4,360 kg/ha) was 4.8, 1.7 and 7.2, respectively (**Table 3**). Average agronomic efficiencies (kg seed/kg nutrient) for N, P_2O_5 and K_2O in this study were 3.6, 4.8 and 3.5, respectively. Significant correlation existed between seed yield and N and P uptake (**Figure 1**). Recommended rates were estimated to be 245 kg N/ha and 86 kg P_2O_5/ha for a target seed yield of 5,000 kg/ha. No relationship existed between seed yield and K uptake, but the apparent balance could be used to determine the recommended K rate. For example, if the target seed yield was 5,000 kg/ha, sunflower used 360 kg K_2O/ha (5,000 x 7.2/100). The average seed yield in K omission plots conducted by IPNI was 3,879 kg/ha and the mean K uptake efficiency was 48%, so a yield increase of 1,121 kg/ha (5,000 - 3,879) would need 168 kg K_2O/ha (1,121 × 7.2/0.48/100). Fertilizer P and K recommendations in the region are commonly based on soil testing and P and K application can be recommended for sunflower at the regular yield levels (4,000 to 5,000 kg/ha) according to **Table 4**.

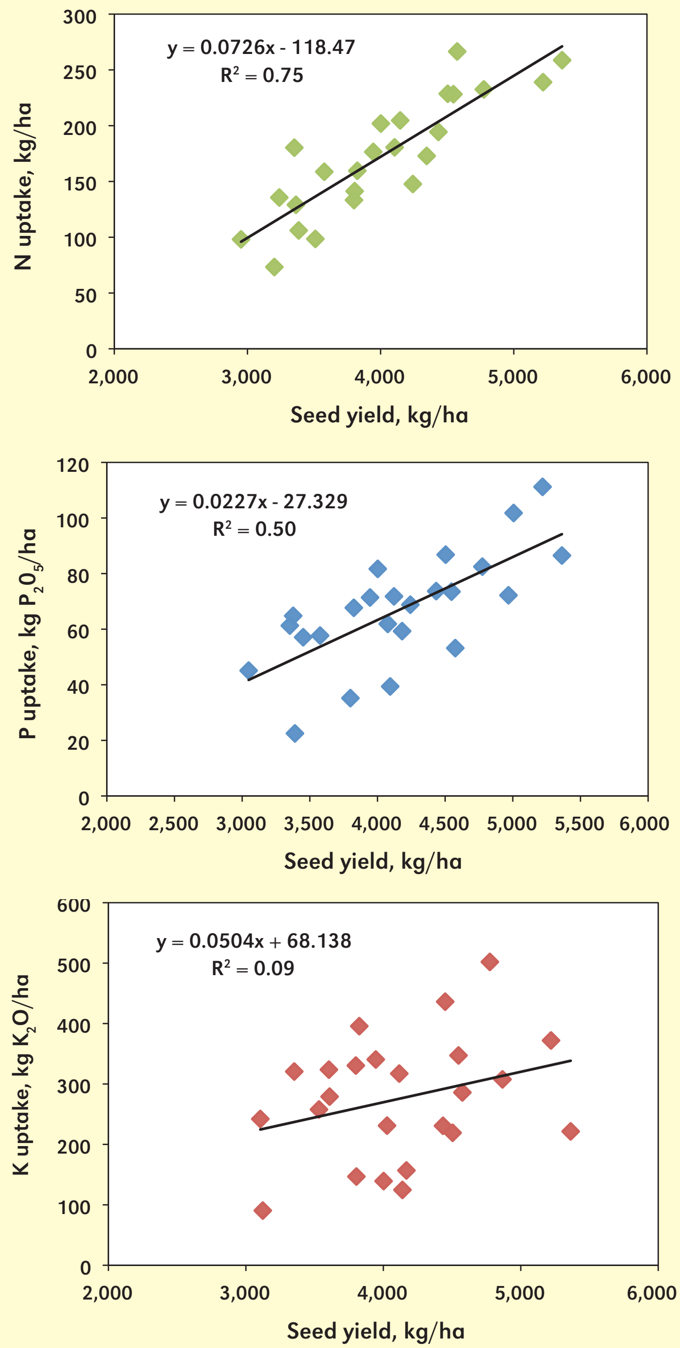

Figure 1. Relationship between sunflower seed yield and N, P, and K uptake.

… the Right Time?

The uptake of N, P and K varies considerably with growth stage of sunflower. At the seedling stage, sunflower has weak roots and poor nutrient uptake ability, and therefore, sufficient nutrient supply is critical at this growth stage. Jiang et al. (2011) indicated that about 50, 55 and 50% of accumulated N, P and K were taken up from budding to flowering stage, while about 35, 25 and 25% were taken up after flowering. Li et al. (2009) indicated that for edible sunflower, N uptake was most rapid from budding to flowering, while P and K uptake was most rapid during the flowering stage. For oil sunflower, rapid uptake of N and K occurs at budding while P uptake peaks from flowering to maturity.

IPNI research in the IMAR has indicated that rapid accumulations of N, P and K occur during 38 to 71 days after emergence (DAE). Although some of the accumulated N, P and K in vegetative tissues transferred to seeds after 56 DAE, sunflower plants still took up 13, 23 and 11% of total accumulated N, P and K after 56 DAE (**Figure 2**). These data suggest that adequate nutrient supply is still important in later growth stages of sunflower. Therefore, topdressing is necessary, and the right time for topdressing N and K is around 38 DAE when the flower disks begin to appear. Vijayakumar and Ramesh (2005) also indicated that split N application resulted in higher growth and seed yield of rainfed sunflower when compared with full basal application before planting.

… the Right Place?

Fertilizers are generally applied in the field by banding, surface broadcasting, broadcasting followed by incorporation, or hole application near the crop row. Banding and broadcasting of fertilizer can be done as basal application before plant-

Table 3. Nutrient uptake and efficiency of sunflower in Inner Mongolia (2008-2012).

	Nutrient applied, kg/ha			Seed yield, kg/ha	Nutrient uptake for producing 100 kg seed, kg			Agronomic efficiency, kg/kg			Nutrient recovery efficiency, %		
	N	P_2O_5	K_2O		N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Mean	206	91	140	4,362	4.76	1.68	7.20	3.6	4.8	3.5	35.5	16.2	47.7
Max	285	165	180	5,363	5.82	2.13	10.51	10.8	7.1	7.2	60.7	23.8	63.0
Min	150	60	60	3,352	3.51	0.93	3.48	1.8	2.5	1.7	23.3	8.4	32.5

Table 4. Fertilizer P and K rate recommendations for sunflower based on soil testing (Bai et al., 2007).

Soil available P, mg P/L	0-7	7-12	12-24	24-40	40-60	>60
Recommended P, kg P_2O_5/ha	180	150	105	75	45	0
Soil available K, mg K/L	0-40	40-60	60-80	80-100	100-140	>140
Recommended K, kg K_2O/ha	255	225	195	150	105	60
Analysis by ASI procedure (Portch and Hunter, 2005).						

ing. Many smallholder farmers do post-emergence fertilizer application by surface broadcasting. Where used, hole application is suitable for topdressing during the crop growth and can save fertilizer because of reduced nutrient losses compared to surface broadcasting. Banding or hole application of fertilizers should be done 6 to 10 cm away from seeds or plant roots to avoid damaging them (Jiang, 2011). For hole application, the depth of the hole depends on fertilizer source and soil moisture. Deep application of fertilizers should be adopted for volatile fertilizers like ammonium bicarbonate or liquid ammonia. In dry seasons, fertilizers should be at greater depth or combined with irrigation to avoid losses and improve their use efficiency.

Summary

The crop production and environmental protection goals of northwest China's sunflower growers are achievable through improved nutrient management. The nutrient needs of sunflower have been defined through local research. The 4R Nutrient Stewardship approach outlines the best options to meet those crop demands. BC

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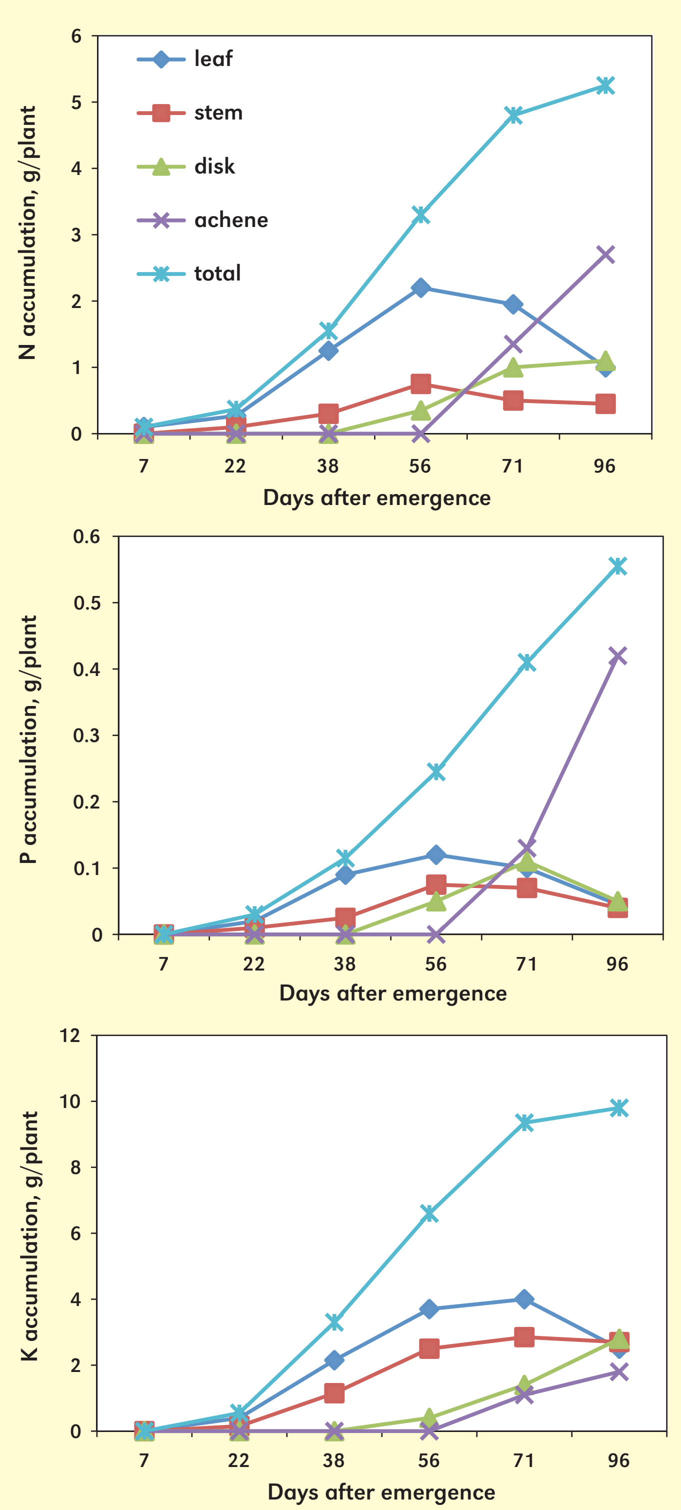

Figure 2. Nutrient N, P and K accumulation by sunflower plants.