NITROGEN USE BY THE CORN PLANT: ROOM FOR IMPROVEMENT

Fred E. Below and Martín Uribelarrea - University of Illinois at Urbana-Champaign

Because too little N can seriously decrease corn yields, many farmers tend to err by making excessive fertilizer N applications. This practice has been rationalized in the past as a cheap form of insurance to assure that enough N is available in case weather conditions support high yields. However, skyrocketing fertilizer N costs, and persistent water quality concerns, are compelling reasons for farmers to improve their fertilizer N management.

One goal of our ongoing research has been to determine the biological N requirement for modern high-yielding corn hybrids. We expect that such information will be useful in either justifying the current N fertilizer recommendation systems, or in developing new systems that take better account of the N needs of modern hybrids.

A series of on-farm and experimentation trials (54 total trials) were conducted over a wide range of cultural practices and production conditions in Illinois over the past five years. In addition to unfertilized plots to assess the soil's capacity to supply the crop with N, we varied the rate of fertilizer applied N (5-7 rates in 30-50 lb. increments) in order to cover the range in amounts needed to optimize grain yield. All other management practices at the individual locations were in accordance with local recommendations considered conducive to high yields. All trials were part of statistically replicated and randomized experiments, and all demonstrated significant N-induced increases in grain yield.

The grain yield response to fertilizer N application averaged over all 54 locations is shown in Figure 1. While grain yield clearly increases as the N rate goes from deficient to sufficient, the response function is quadratic, with a biologically optimum N rate of about 155 lbs. N/acre to produce 177 bushels. Somewhat surprising were the relatively high yields produced without any supplemental N, which were generally over 115 bushels per acre.

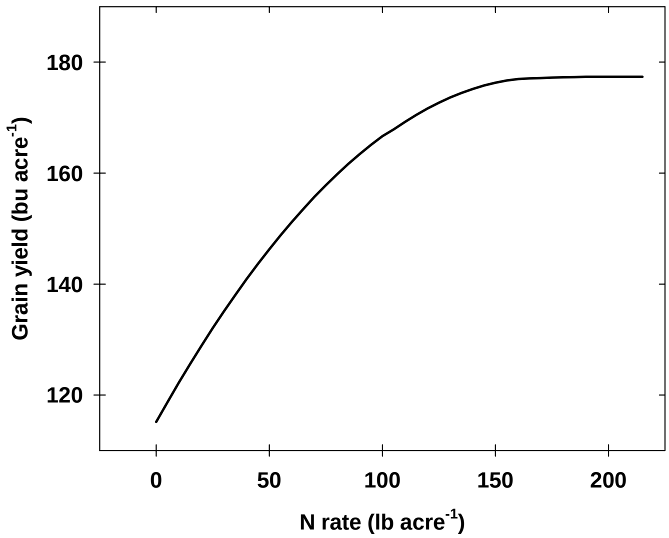

Figure 1. Grain yield response of corn to supplemental fertilizer N. Data are the average of 54 N response trials conducted in Illinois over a five-year period (2000-2004).

Averaged over locations and years our calculated biologically optimum N rate averaged slightly less than 0.9 lbs. of N per bushel, with a range of almost 0 to1.3 lbs. A histogram of the number of locations with a particular N requirement is presented in Figure 2. In only six instances was 1.2 lbs. of N per bushel of grain (the University of Illinois N requirement coefficient) needed to optimize productivity, and in most cases, considerably less N per bushel was required. Averaging the location yields within each N-requirement group showed that the highest N requirements were typically associated with the lowest-yielding environments (Figure 3). Conversely, locations with the highest yields tended to have lower per-bushel N requirements, presumably because the soil supplied the N in these productive environments. These findings show that N rates higher than current University of Illinois recommendation are not necessary, and refute a common rationalization used for over applications (i.e. to make sure that adequate N is available in case the environment is supportive of high yields).

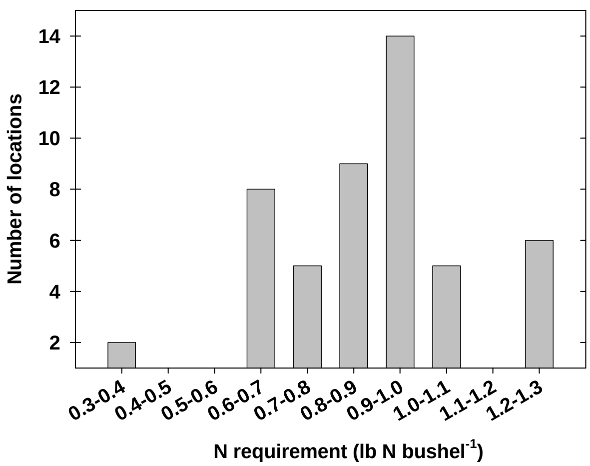

Figure 2. The number of individual locations exhibiting a particular N requirement needed for maximum grain yield. The N requirement could not be determined for four of the 54 locations due to either a lack of response, or to a linear response to N.

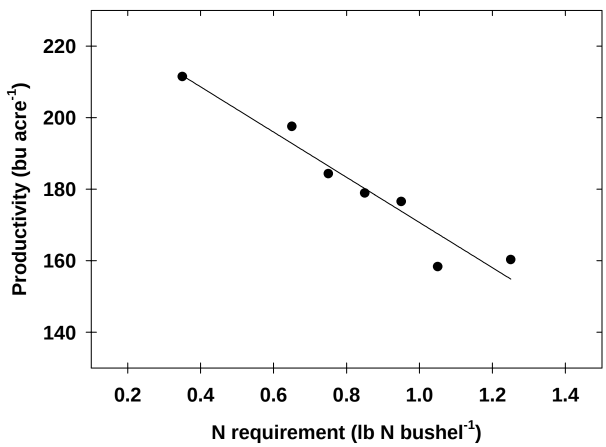

Figure 3. The relationship between productivity potential and the N requirement needed to achieve maximum grain yield. Productivity potential was estimated as the average yield among the locations within each N requirement group depicted in Figure 2.

Yield monitors usually reveal areas of differing productivity within individual corn fields. Intuitively, at least some of this variability should be manageable by altering production inputs, most notably fertilizer inputs. Prerequisites for successful use of variable rate nutrient applications are: (1) that areas of differing nutrient supply exist in the field; (2) that these areas can be easily and readily distinguished; and (3) that judicious application of the nutrient improves yield and/or reduces overall fertilizer use. These prerequisites are most completely met for fertilizer N use, where N deficiency is fairly obvious as paler color and death of lower leaves, and where different field areas are likely to have varying levels of available N due to differences in the rate of N mineralization and/or the degree of N loss. Because selecting the proper N rate is crucial for maximal corn productivity, applying fertilizer N where it is most likely to achieve a positive yield response could simultaneously make the farmer more money and minimize the environmental impact of N fertilizer use.

Experiments were conducted in 2003 on four commercial-size fields in and around Beardstown, Illinois, to assess the variability in responsiveness to fertilizer N within individual fields. We varied the rate of fertilizer applied N (rates of 0, 100, 150, 200 and 300 lbs. N/acre) and sampled each field at maturity in a manner that allowed for determination of both N rate effects and field spatial variability.

Although all four fields exhibited a positive yield response to incremental increases in N supply, there were differences among the fields in the type of response function, and in the degree of responsiveness to N (Figure 4). The field averages of three of the four fields exhibited the typical quadratic response to incremental increases in N supply, while surprisingly in one field, the yield response to N was linear up to 300 lbs of N.

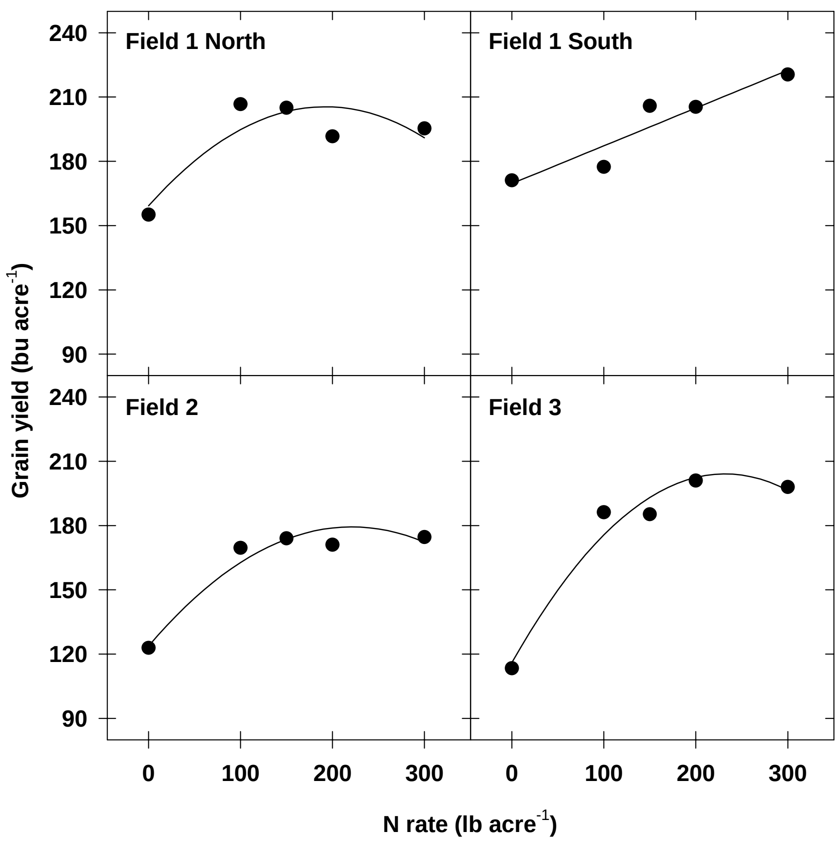

Figure 4. The grain yield response to supplemental N for four fields near Beardstown, Illinois, in 2003.

All four fields also had regions where the grain yield response to N was distinctly different from the field average; and all fields had areas of no, or minimal response, and areas of linear response to fertilizer N. An example of this variation in grain yield within the two halves of Field 1 (a 160 acre field divided into North and South) is shown in Figure 5. Conversely, grain protein (the storage form for N in the grain) was generally more responsive to fertilizer N than was grain yield, with many of the regions exhibiting linear increases in grain protein with increases in the N supply (Figure 6). These changes in grain protein demonstrate the success of the variable N treatments in altering the supply of N available to the plant.

Each of the 10 regions depicted represents approximately 2.5 acres, and the yield and grain protein data clearly show that all areas of these fields did not respond the same to fertilizer N applications. This type of in-field variability is a prerequisite for devising variable rate technologies for optimizing fertilizer N applications, and we are currently evaluating some of these technologies.

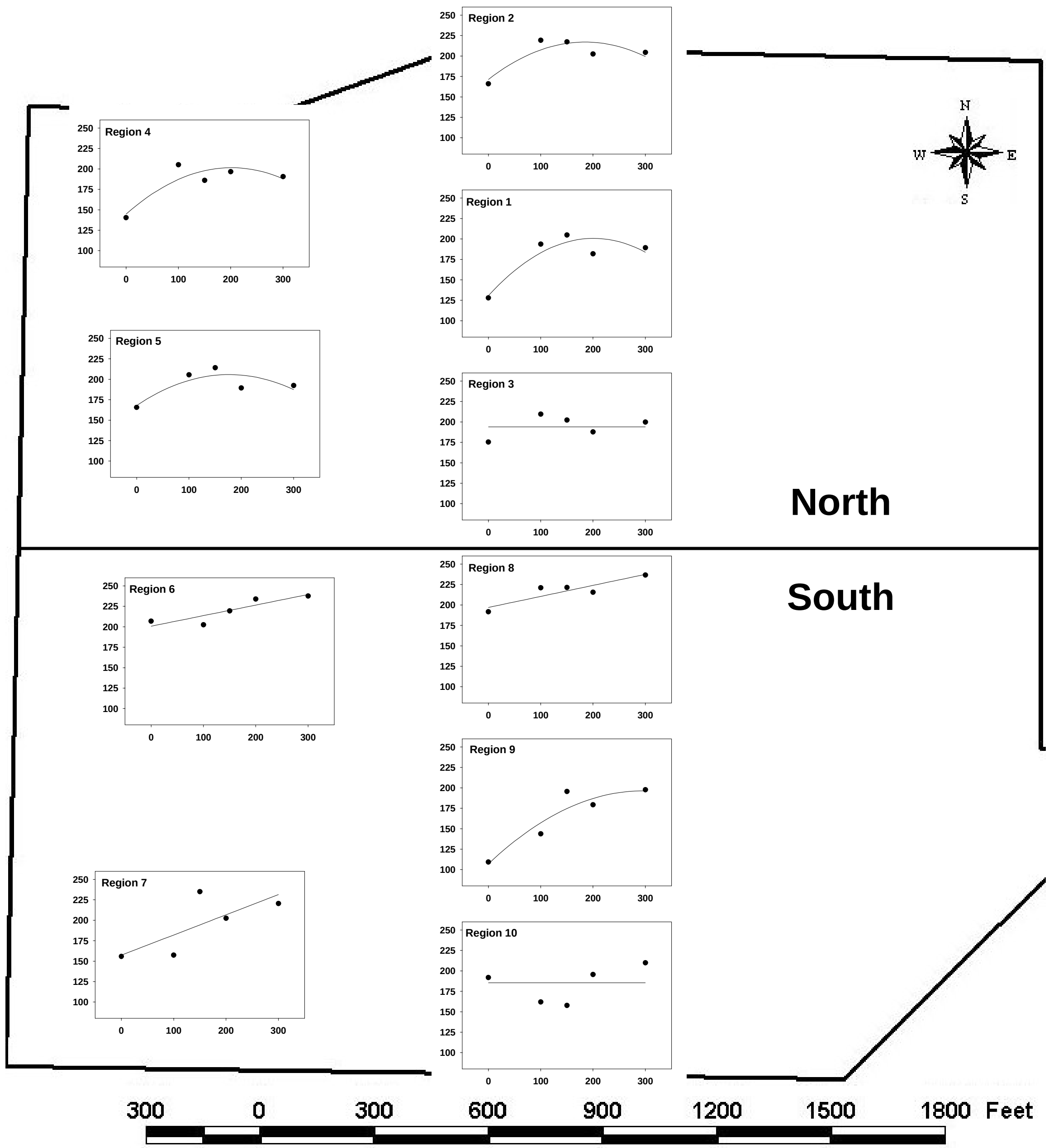

Figure 5. Within field variability in grain yield (bu. acre) response to supplemental N for two halves of a 160-acre field near Beardstown, Illinois, in 2003.

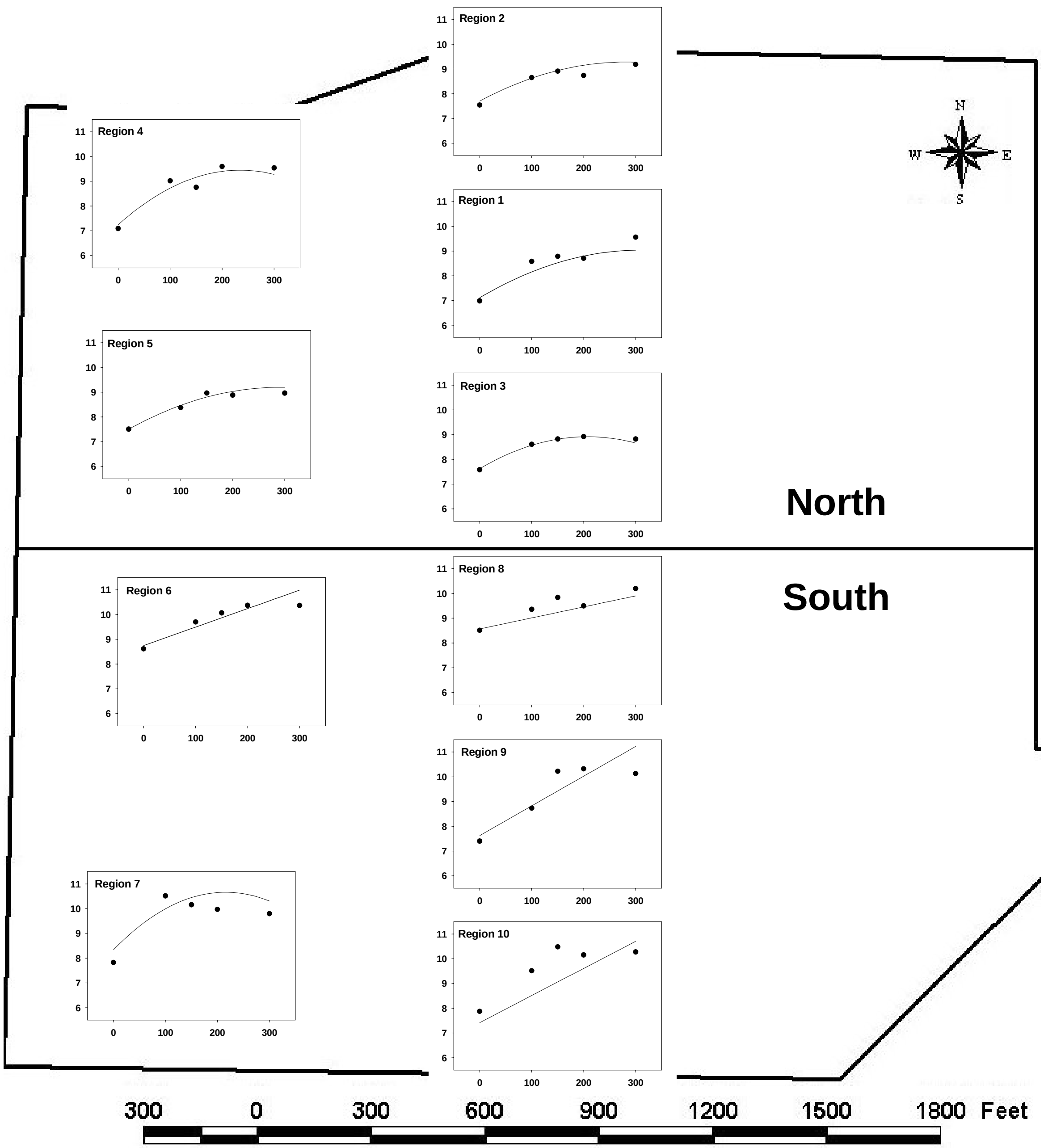

Figure 6. Within field variability in grain protein (%) response to supplemental N for two halves of a 160-acre field near Beardstown, Illinois, in 2003.

Hybrid selection is another major grower choice that can potentially affect N fertilizer management, as there can be considerable variation in N use among commercial hybrids. We demonstrate this variation with data from a hybrid by N rate experiment conducted at the Crop Sciences Research & Education Center in Urbana, Illinois, in 2004. Twenty-five commercial hybrids were grown in replicated plots with 0, 150, and 300 lbs. per acre of N, and all other conditions conducive to high yields.

The 0 lb. N rate was designed to evaluate productivity under N limiting conditions, the 300 lb. rate under non-limiting N, and the 150 lb. rate to be roughly similar to the normal production recommendation. The hybrid brand names and their relative maturity rankings are shown in Table 1. These hybrids were divided into two groups according to their relativity maturity, with those less than 113 days considered short-season and those 113 days or longer considered full-season.

Table 1. Commercial hybrids evaluated for their response to fertilizer N at Urbana, Illinois, in 2004.

Hybrid name		Relative maturity (days)
AgriGold	6417	107
	6467	110
	6477	111
	6490	112
	6617	115
Asgrow	RX715	111
Azea	6406	113
Becks	5827	111
	6827	114
Burrus	582	108
	442	111
Crows	9851	114
	7651	110
Golden Harvest	8991	111
	9229	112
	9249	113
Pioneer	34H31	109
	33J24	112
	33P67	114
	32D12	114
	32W86	114
	32H69	117
	31N27	118
Wyffels	5540	108
	8540	114

Averaged over the 25 hybrids, N fertilization increased grain yield by 54 bushels per acre over the unfertilized plots, with 48 bushels of this increase coming with the first 150 lb. increment of N (Table 2). While the six bushel yield increase as the N rate was increased from 150 lbs. to 300 lbs. was statistically significant (LSD of 6, $P \leq 0.05$), it would clearly not be economically advisable to apply this level of N. Rather, we used the 300 lb. N rate as an upper limit above which we were fairly certain there would be no additional yield response to N. Interestingly, this supra-optimal N rate compressed the yield range among these hybrids to only 47 bushels, compared to 71 bushels with 150 lbs. of N and 62 bushels with 0 lbs. of N (Table 2). Most of this compression was at the lower limit of the hybrid range which increased by 30 bushels from 152 to 182 bushels per acre (Table 2). Averaged over the three N rates, the yield range among the 25 hybrids was 54 bushels (150-204 bushels per acre), which coincidently is the same range that was observed for N response. These data demonstrate the importance of both proper N management and hybrid selection in optimizing corn productivity, as both inputs can independently influence yields by as much as 50 bushels.

Table 2. The variation in grain yield of 25 commercial corn hybrids associated with N rate and with hybrid.

N rate	Grain yield	Hybrid range
Lbs. acre	Bu. acre^{-1}	
0	146	112 - 174
150	194	152 - 223
300	200	182 - 229

Although the overall hybrid by N rate interaction was not statistically significant ($P = 0.20$), the relative maturity group ranking (short- vs. full-season) by N rate interaction was significant ($P \leq 0.025$). This difference in N response between the relative maturity group rankings is shown in Figure 7. While the short- and full-season groups produced similar average yields with 0 lbs. and 300 lbs. of N, the short season hybrids were superior at 150 lbs. per acre of N. Differences attributed to relative maturity is one of many ways that corn hybrids can vary in their use of fertilizer N, and we are continuing to examine other strategies in our quest to identify plant characters that are associated with efficient N use.

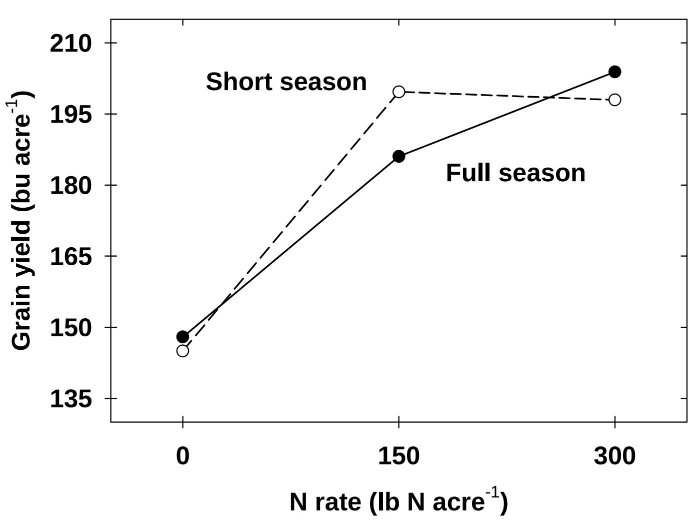

Figure 7. Grain yield response to supplemental N for the 25 corn hybrids grouped according to their relative maturity. Short-season hybrids (13 total) were considered less than 113 days and full-season hybrids (12 total) 113 days or more.