

# Managing the Seed-Corn Supply Chain at Syngenta

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Each year, Syngenta Seeds, Inc. produces over 50 seed-corn hybrids and the following year markets over 100 hybrids under the NK brand name. The fact that growing seed corn is a biological process dependent upon local weather and insect conditions during the growing season complicates production planning. In addition, customers' experiences with a particular hybrid during a given year strongly influence demand for that hybrid during the next year. To help mitigate some of these yield and demand uncertainties, Syngenta (and other seed companies as well) take advantage of a second growing season for seed corn in South America, which occurs after many of the yield uncertainties and some of the demand uncertainties have been resolved or reduced. To better manage this production-planning process, Syngenta and the University of Iowa developed and implemented a second-chance production-planning model. A trial of the model showed that using it to plan 2000 production would have increased margins by approximately \$5 million. Today, Syngenta uses this model to plan production for those varieties that account for 80 percent of total sales volume.

*(Inventory: production, uncertainty. Industries: agriculture, food.)*

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Each spring, farmers (consumers of seed corn) decide how to allocate their land among a variety of possible crops, one of which is corn, at least in many areas including the Midwest. After deciding how much of their land to plant in corn, farmers must decide which hybrid(s) to purchase and plant. There are literally hundreds of different hybrids produced either by one of eight firms (including Syngenta) that account for approximately 73 percent of the total United States market of approximately \$2.3 billion or by one of the over 300 smaller regional firms that account for the remaining 27 percent. These hybrids differ in their resistance to certain diseases and insects as well as their performance under different soil and climatic conditions. Certain hybrids, for example, are optimized for the shorter, cooler northern corn belt while others are optimized for the longer, hotter southern corn belt. The

choices particular farmers make are, therefore, highly dependent upon their locations.

In addition, farmers' decisions may be heavily influenced by their experience during the previous growing season. Suppose, for example, a farmer happened to choose a particular hybrid intended for a cooler, less humid climate. If the weather happened to be abnormally hot and humid in that growing season, the farmer would likely have a much lower yield than he or she expected and hence would be less inclined to purchase that particular hybrid again. Conversely, if the hybrid chosen happened to be optimized for the growing conditions as they actually occurred, the situation would be reversed. If the hybrid were new and hence not thoroughly tested, very few growers would be inclined to make large plantings. Instead they would tend to make small test plantings to evaluate

the hybrid's performance under their local growing conditions.

Because seed corn cannot be produced instantaneously but instead must be produced over a long summer growing season, Syngenta and other seed companies must rely on their inventories of seed corn produced in previous growing seasons to fill farmers' demands for the current growing season. The production of hybrid seed corn can be briefly described as follows. A hybrid is the genetic cross of two genetically different parent inbred plants. To produce the genetic cross (or hybrid) that will be sold as seed corn, the seed company or its contractor grows these two parent inbreds in the same field in alternating rows. As the plants mature, the tassels from one of the parents (called the female plant) are removed in a labor-intensive "detasseling" operation, thereby insuring that the only pollen available to pollinate the female plant must come from the other parent (called the male plant). The resulting corn that matures on the female plant is, therefore, a genetic cross of its two parents. Once corn from the female matures, the seed company picks it and transports it to processing plants where it is dried, sorted, treated with antifungal or other coatings, bagged, and stored in anticipation of the upcoming selling season.

Thus, production to meet the demand for seed corn for the 2002 growing season actually occurs in 2001 (or earlier) during one of two growing seasons: the North American growing season in which seed-corn parent stock is planted in the spring and harvested in late summer or the South American growing season which is offset by approximately six months.

Syngenta plans for 2001 seed-corn production prior to the time when it actually knows the final demands for 2001 seed corn. But, when it plans 2001 production, Syngenta knows the following with a fair degree of certainty:

- Inventory on hand to meet 2001 demands,
- Production costs for North American production, and
- Production costs for South American production.

What it does not know with certainty are the following:

- Demand during 2001,

- Average yields for 2001 North American production of seed corn,

- Average yields for 2001 South American production of seed corn, and

- Demand during 2002.

Much of the variability of seed-corn demand in any year is due to the variability of experiences with particular hybrids during the previous growing season. When it plans 2001 production, Syngenta knows about those experiences (which affect demand during 2001) for the year 2000. Thus, for the 2001 planning process, demand during 2001 may be regarded as far more certain than the demand that will exist during 2002 (Figure 1). During this first phase of the planning process, prior to spring planting, Syngenta determines, for each hybrid, how much acreage to plant for the 2001 North American production period and makes a contingent 2001 production plan for South America.

In the second phase of the planning process later in the year, it updates and finalizes the production plan for South America. At this point, Syngenta knows the final 2001 demand and the average yields from North American production; the only significant uncertainties remaining are the average yields from any planned South American production and the demand during the 2002 sales period.

Inputs to the first-stage planning process include

- Information about on-hand inventories of seed corn,

- Projected demand during 2001,

- The distributions of yield in both North and South America,

- The distribution of demand during the year 2002,

- The selling price of seed corn, and

- The costs of both North and South American production.

In the planning process, planners decide about how much acreage to devote to producing each variety of seed corn in both North and South America.

In recent years, competition from other firms and research leading to new proprietary genetics have combined to shorten product life cycles. As a result, each year fewer hybrids have a long, stable demand history that would make forecasting demand easy. Instead, more hybrids are either beginning their life cycles with little certainty regarding their demand or

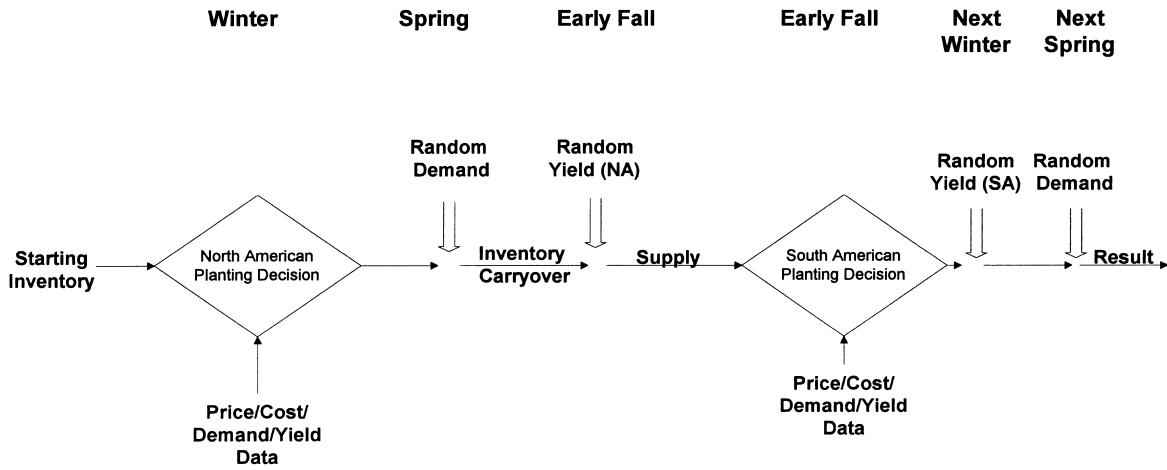


Figure 1: The seed-corn planning process accounts for a second chance at production in South America.

ending their life cycles with predictable but declining demand. Because of the shortened product life cycles, production planning has become more crucial to the success of the company and simultaneously more challenging.

## Modeling

The impetus for studying and modeling the seed-corn planning process came from a conversation between one of the University of Iowa researchers and a student in the evening MBA program. That evening's class had included a discussion of the single-period news-vendor model in which there is a single chance to order or produce a product to meet a subsequent random demand (Figure 2).

The instructor mentioned planning seed-corn production as a possible application for such a model, suitably modified to incorporate the fact that production yield is a random variable. After class a student who worked for one of the largest seed-corn producers in the world mentioned that planning for seed corn was actually a more complicated process. During the ensuing conversation, the student explained that the process was complicated primarily because South American production, offset by approximately six months, provides the company with a second chance to produce seed corn for sale in the next marketing season.

After some initial modeling efforts, the University of

Iowa researchers contacted Syngenta to see if the company had any interest in pursuing a joint research effort aimed at better understanding and modeling the seed-corn planning process. Syngenta agreed to provide information on the seed-corn industry, its crop growing practices, and specific data regarding demand distributions, yield distributions, seed-corn prices, and production costs. In return for providing this information and for serving as a beta test site, Syngenta obtained the right to use any resulting software and models for its own production planning.

The university team modeled the seed-corn planning process as a two-stage (corresponding to North

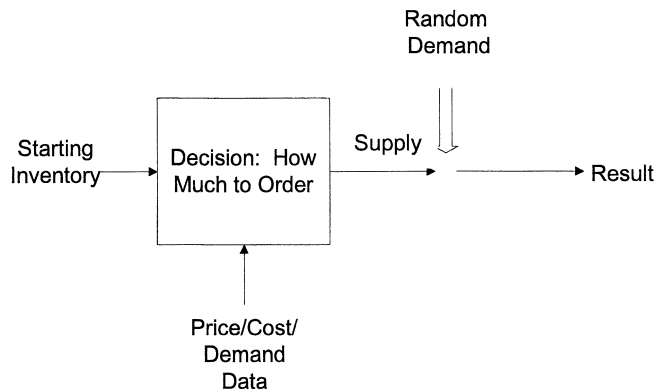


Figure 2: The news-vendor planning process considers only one chance to procure product.

American and South American planting decisions) dynamic programming problem, the objective of which is to maximize expected gross margin. Jones et al. (2002) illustrate the value (increase in expected margin) of two production opportunities versus one. Figure 1 is a graphical representation of the model developed with one exception; a certain demand equal to the expected demand replaces the first random demand. The primary reason for this change is that the first stage of the planning process takes place just before spring demand occurs, and by that time, most of the original uncertainty regarding that demand has been resolved. As a result, we found that incorporating the spring demand as a random variable rather than as a certain demand complicated the model and enlarged its data requirements without providing any significant benefits.

To be very specific, the model requires the following pieces of information:

- The sales price per unit (unit = 80,000 kernels) of seed corn,
- The shortage cost per unit of seed corn,
- The salvage value per unit of unsold seed corn,
- The cost per unit of processing and shipping seed corn (for both North and South America),
- The cost per acre of planting, managing, and harvesting seed corn (for both North and South America),
- The probability distribution for next year's demand for seed corn, and
- The probability distribution of seed corn yield (based on units per acre for both North and South America).

Most of these data items are quite straightforward and were obtained by examining historical financial, accounting, and production data. Three of these items, however, required some effort: shortage cost, salvage value, and demand distribution. Determining the appropriate shortage cost required input from the finance, accounting, and marketing groups at Syngenta. After much discussion and analysis, we approximated shortage cost as the lost profit from two years' worth of sales. Thus, if the profit per unit sold is  $\$x$ , the shortage cost is  $\$2x$ . Leftover seed corn can be stored and used to meet demand the following year. Salvage value, therefore, is closely approximated by the expected cost of producing seed corn less the cost of storing it until the next year. Seed corn, however, can be

carried in inventory for a limited number of years because seed that is too old has a very low germination rate. We estimated the demand distribution from historical data. To do this, we obtained data records that provided 207 observations of forecasted demand and actual demand for different hybrids. First, we normalized the data by dividing, in each case, the actual demand by the forecasted demand, providing us with a

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**Syngenta estimates that using the model will increase margins by several million dollars.**

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total of 207 ratios. We then estimated a distribution of these ratios (the normalized demand distribution) by constructing a histogram from the 207 ratios. This histogram shows, for example, what percentage of the time actual demand was between 90 percent and 100 percent of forecasted demand. To obtain the actual demand distribution used in the model, we then multiplied forecasted demand, a datum, by the distribution of ratios (the normalized demand distribution). Because we used linear programming to model the problem, we used discrete approximations for both demand and yield distributions. We chose all the data used in constructing the normalized demand distribution for years and for hybrids for which actual inventory was left on hand after the sales period. This is important because otherwise we would not have been able to say with certainty what actual demand was—had ending inventory been zero, all we could have said is that demand exceeded supply.

In applying the model, the analyst first runs it prior to spring planting using the best estimates of demand and yield distributions available at that time. The outputs for each hybrid variety from this initial application are recommendations on

- How many acres to plant for the North American growing season, and

- For each possible value of North American yield, how many acres should be planted for the South American growing season.

At the end of the North American growing season just prior to planting in South America, the analyst also runs a simplified single-growing-season version of the

model. At the time of this second run, Syngenta knows North American yield and, based on information accumulated during the current growing season, can update estimates of South American yield and next year's demand prior to running the model. The output from this second model run is a recommendation on how many acres to plant in South America.

The objective for both stages in the dynamic programming recursion is to maximize expected gross margin: expected revenue from seed-corn sales less expected costs of production, holding, and shortage. The objective function is either a sum or an integral of concave functions, depending upon whether or not the probability distributions are discrete or continuous. As a result, the objective function itself is concave, so the model is well posed. However, we pose the problem as a linear program and solve it using the What's Best! add-on to Microsoft Excel.

Our model treats each hybrid independently of others. Although one might suspect that some production constraint (land availability, for example) would link the different hybrids, this is not the case. Syngenta has enough opportunities to contract out the production of seed-corn to outside producers that availability of land and availability of other production inputs are not constraints.

## Implementation

Syngenta's original production planning process was iterative: First, the marketing group collected estimates of next year's sales from its sales force and used them to develop an aggregate demand forecast. Typically, senior managers imposed production constraints and financial constraints that precluded producing everything Marketing wanted. To resolve the differences, marketing representatives and their counterparts from Production, Finance, and Accounting usually held many meetings in which they negotiated to arrive at a yearly production plan. Typically, they regarded South American production only as a reactionary rescue event to help overcome a shortfall resulting from an unexpectedly poor yield in North America. They drew up the typical North American production plan, therefore, under the assumption that North American production would have to cover demand.

Because formal modeling procedures, at least those based on optimization methods, were new to Syngenta's production planning process, Syngenta insisted on validating the model and its results before using it in practice. To do this, Syngenta selected four hybrid varieties that company representatives believed to represent the range of typical varieties and for which detailed information was available regarding

- Production costs,
- Yield estimates at the time production decisions were made,
- Demand estimates at the time production decisions were made,
- Actual (realized) yields, and
- Actual (realized) product demands.

In the study, we ran the model for each of the four hybrids in each of the two years of the study (Tables 1 and 2). The idea was to compare what Syngenta actually did to what would have happened if it had used

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## One major benefit is the reduction in forecasting bias.

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the model and followed its recommendations with no modification. For each model run, we used the yield distributions and demand distribution that Syngenta could have used at the time it made the acreage decisions. Yield distributions and cost data were different for North America and South America. Once the model-computed planting acreages were available, we made the assumption that realized yields for the model scenario would have been the same as the yields that were actually observed. It should be noted that Syngenta recorded forecasted demand to the nearest 1,000 units and recorded sales to the nearest 100 units while recording acres, actual production, and inventories to the nearest unit. The results adopt the same reporting convention (Tables 1 and 2).

To go into this in more detail, we will consider Hybrid A for year 1 of the study period. The seed company forecasted a demand of 67,000 units in year 1 for this particular hybrid. It expected a yield, based on prior harvest data, of 41.2 units per acre and actually planted 1,507 acres in North America (in the summer

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	Hybrid A		Hybrid B	
	Actual	Model	Actual	Model
Year 1				
Initial inventory	28,678	28,678	121,614	121,614
Forecasted demand	67,000	67,000	275,000	275,000
Acres planted	1,507/0	1,844/0	4,827/1,009	4,264/0
N.A./S.A.				
Production	69,322	84,824	339,386	271,198
Sales	72,000	72,000	396,000	392,812
Inventory carryover	26,000	41,502	65,000	0
Margin	<b>\$3,836,480</b>	\$3,197,713	\$25,119,572	<b>\$28,410,563</b>
Year 2				
Initial inventory	26,000	41,502	65,000	0
Forecasted demand	164,000	164,000	409,000	409,000
Acres planted	4,697/0	3,687/0	9,992/0	8,465/0
N.A./S.A.				
Production	232,502	182,492	656,474	556,136
Actual sales	146,000	146,000	229,000	229,000
Inventory carryover	103,000	77,994	492,474	327,135
Margin	\$4,930,685	<b>\$6,650,799</b>	\$391,190	<b>\$4,257,127</b>

**Table 1:** This table shows the model results versus the actual results for Hybrids A and B. Although the model does not outperform decisions actually taken in every case, using the model would have improved margins over the two-year period by approximately 12 percent for Hybrid A and by 28 percent for Hybrid B. The entries for inventory carryover are the number of units after sales carried into the next year. Entries in bold represent higher margin outcomes.

prior to the year 1 sales period) and 0 acres in South America. The actual planting decision of 1,507 acres, when multiplied by the expected yield of 41.2 units per acre, results in an expected production of 62,088 units. When added to initial inventory of 28,678 units, the expected total supply would have been 90,766 units. The firm planned for overproduction because the costs of shortages are much larger than the costs of overproduction (because excess inventory can be carried over for sale the next year). The company has a financial incentive to weight its decisions towards avoiding shortages rather than avoiding excess inventory. Its actual yield was 46 units per acre for a total production of 69,322 units. Its total supply (including inventory carried over) was 98,000 units.

For the model run for this problem, we used a yield distribution that ranged from 31.2 to 51.2 units per acre, with an expected yield of 41.2. We generated the demand distribution by multiplying 67,000 (forecasted

	Hybrid C		Hybrid D	
	Actual	Model	Actual	Model
Year 1				
Initial inventory	0	0	16,717	16,717
Forecasted demand	43,000	43,000	43,000	43,000
Acres planted	780/0	587/0	2,528/320	1,396/0
N.A./S.A.				
Production	28,392	21,372	145,283	72,464
Open-market purchase	31,000	8,807	0	0
Sales	26,600	26,600	95,000	89,181
Inventory carryover	32,792	3,580	67,000	0
Margin	-\$295,848	<b>\$876,607</b>	\$3,364,508	<b>\$5,822,088</b>
Year 2				
Initial inventory	32,792	3,580	67,000	0
Forecasted demand	33,000	33,000	116,000	116,000
Acres planted	0/0	749/0	1,900/0	2,967/0
N.A./S.A.				
Production	0	32,220	85,880	134,128
Sales	22,000	22,000	47,600	47,600
Inventory carryover	10,792	13,800	105,280	86,528
Margin	<b>\$1,486,872</b>	\$459,723	<b>\$648,680</b>	-\$365,994

**Table 2:** This table shows the model results versus the actual results for Hybrids C and D. Although the model does not outperform decisions actually taken in every case, using the model would have improved margins over the two-year period by approximately 12 percent for Hybrid C and by 36 percent for Hybrid D.

demand) by the normalized distribution. Using the model, the production plan for North America was 1,844 acres. If the company had planted this many acres and had obtained the same yield of 46 units per acre, the total production would have been 84,824 units. Because the actual North American yield of 46 units per acre was much larger than the expected yield of 41.2 units per acre, the model's second-period production plan, computed after period 1 yield is known, called for 0 acres in South America. Combined with carryover, using the model's production plan would have given Syngenta a total supply of approximately 113,502 units. Because actual demand was 72,000 units, the company actually carried over 26,000 units to the next year. Using the model's production plan would have led to a carryover of about 41,502 units.

In both cases, supply was sufficient to meet demand, so revenue was the same. To determine margin, we subtracted planting and harvesting costs as well as

carryover costs from revenues. In this case, the model's production plan incurred extra planting and harvesting costs as well as extra inventory carrying costs, so the year 1 actual margin realized by the company was greater than what it would have earned had it used the model.

Continuing on to year 2 with the same hybrid, the company forecasted a demand of 164,000 units, planted 4,697 acres in North America and eventually sold 146,000 units. The model's production plan called for 3,687 acres to be planted in North America. The model called for lower second-year acreage partly because the carryover from year 1 would have been larger using the first period acreage it specified. Had the company used the model's suggested acreage decision in year 1, its year 1 margin would have been lower than it actually obtained. By using the model in year 1 and year 2 for this hybrid, however, it would have obtained an overall (over the two-year interval) margin increase of approximately 12 percent.

For Hybrid B, the seed company forecasted a demand of 275,000 units in year 1. It expected a yield, based on prior harvest data, of 59.6 units per acre in North America and 45 units per acre in South America. The company actually planted 4,827 acres in North America and 1,009 acres in South America. Its actual yield was 63.6 units per acre in North America and 32.1 units per acre in South America for a total production of 339,386 units. Its total supply (including inventory carried over) to face year 1 demand was 461,000 units.

For the model run for this problem, we used a yield distribution that ranged from 39.6 to 79.6 units per acre, with an expected yield of 59.6 for North America (the corresponding numbers for South America were 23, 69, and 46 respectively). We generated the demand distribution by multiplying 275,000 (expected demand) times the normalized demand distribution. Using the model, the production plan for North America was 4,264 acres. If the company had planted this many acres, using the realized 63.6 units per acre figure, the total production would have been 271,198 units. Because the actual North American yield of 63.6 units per acre was larger than the expected yield of 59.6 units per acre and there was a substantial carryover from the previous year, the model's South American production plan called for zero acres in South America.

Combined with carryover, the yield based on using the model's production plan would have given Syngenta a total supply of 392,812 units. Because actual demand was 396,000, Syngenta actually carried over 65,000 units to the next year. Had it used the model's production plan, Syngenta would have had a shortage of 3,188 units.

To determine margins, we subtracted planting and harvesting costs and carryover and shortage costs from revenues. In this case, the model's production plan incurred lower planting and harvesting costs and lower inventory carrying costs than the company had actually incurred, so the year 1 actual margin realized by the company was substantially less than what it would have earned had it used the model.

Continuing on to year 2 for Hybrid B, the company forecasted a demand of 409,000 units, planted 9,992 acres in North America (no South American acres), and eventually sold 229,000 units, leaving an inventory carryover of 492,474 units. The model's production plan called for 8,465 acres to be planted in North America, which would have led to a production level of 556,136 units and an inventory carryover of 327,135 units. In summary, using the model's suggested acreage decision in year 1 instead of the company's actual decision would have led to an increase (relative to what the firm actually realized) in year 1 margin of about \$3,000,000. The additional improvement that would have occurred in year 2 for this hybrid would have given it an overall (over the two-year interval) margin increase of about \$7 million.

The actual results versus the model results for Hybrids C and D are documented in Table 2. As with Hybrids A and B, the model does not always outperform decisions actually taken, but on an aggregate basis it would have improved performance. In fact, aggregating results for the four hybrids over the two-year study period shows that margins would have improved by more than 24 percent while inventory carryover would have been reduced by 27 percent.

These data, limited though they are, suggest that using the model would indeed produce production plans quite different from those the company actually adopted. On average, the model's production plans produce less inventory carryover and greater margin

than those actually adopted. Also, the model tended to plant a smaller acreage than Syngenta actually did.

Although the results of this experiment appeared promising, the production plans the model recommended were quite different from those Syngenta produced by using its current production-planning process. The senior managers decided that the model would have to prove itself further before they would adopt it as part of the planning process. To test the model further, they decided to use the model to develop an independent production plan in parallel to their ongoing processes for planning production for 2000 to produce seed corn to sell in 2001. Syngenta first developed production plans for 18 of its top hybrids using its normal procedures. These production plans were the ones actually implemented in 2000.

Afterwards, we ran the model on the same 18 hybrids using the same demand, yield, and cost data that had been inputs to the normal procedures. Syngenta kept track of actual production yields and actual year 2001 seed-corn demands for these 18 hybrids. In June 2001, after sales results for 2001 were finalized, it could therefore compare what actually happened with what would have happened if it had followed the model's recommendations. This side-by-side comparison showed that, by using the model and implementing its recommendations, Syngenta would have planted fewer acres, would have had less inventory to carry over, and could have increased its margins by approximately \$5 million on these 18 hybrids.

The final results of the 2000 production-planning experiment were not known until June 2001, well after the 2001 production plan had to be implemented, but preliminary results from the experiment had indicated margin improvements in the same range as actually occurred. As a consequence, Syngenta regarded the 2000 production planning experiment as a successful test of the model and decided to use the model beginning in 2001 to help plan production of hybrids in three classes:

- Top selling hybrids comprising 80 percent of its total sales volume,
- New hybrids with high demand uncertainty, and
- Late life cycle hybrids with established but declining demand.

Based on historical data, we developed different demand distributions for the hybrids in each of these three classes, using the modeling procedure described earlier.

Currently, the vice president of supply management runs the model with input from marketing, production, and inventory managers. A team of managers from these three areas decides whether to follow the model outputs. Each year, Syngenta modifies certain model parameters (yield distributions, demand forecasts, and normalized demand distributions) to account for the most recent information. It takes several weeks to accumulate the required model inputs, but actually running the model and analyzing its output takes only one to two days. It performs first runs of the year (two-period model) in late February or early March to allow adequate time for production contracting. It performs second runs of the model (one-period model) in late August or early September to confirm the South American production decisions.

## Impact

In developing and implementing the model, we clearly demonstrated the existence of systematic bias in the demand forecasts. Specifically, we found that the historical demand forecasts Syngenta had produced using the traditional aggregation or roll-up methods overestimated demand 73 percent of the time. By using the model to analyze various realistic scenarios, we found that eliminating the bias in forecasting procedures could produce substantial benefits. This has spurred Syngenta to thoroughly review and modify its forecasting process. For 2002, it organized a team dedicated solely to forecasting and inventory management with the goal of reducing the inventory-to-sales ratio.

Using the model has changed the way Syngenta thinks about and values a second chance at production in South America. Before we developed the model, it saw South American production merely as a high cost tool for adjusting inventory. Now, it sees the second-chance opportunity in South America as a viable inventory-management tool and plans for it, making it an integrated event rather than a reactionary rescue event. Even when Syngenta does not use South American production, the fact that it is an available option

enables it to reduce the acreage in North America it devotes to seed-corn production. As a result, Syngenta has been able to reduce its working capital while still meeting customer demands for seed corn.

A key example of Syngenta's change of thinking is that it now contracts for South American production in advance. As a result, Syngenta has been able to choose better growers at reduced prices, allowing it to better predict yield, to reduce production costs, and to come close to its inventory goals.

Since implementing the model, Syngenta has analyzed industry benchmarks to investigate how its leading competitors use the second-chance production opportunity in South America. It found that on average, seed-corn companies sell only 60 percent of the seed corn they produce in South America each year, storing the remaining 40 percent until the next year. By using the model, Syngenta has improved its use rate of seed grown in South America to 80 percent. Since producing seed corn in South America is a costly option, Syngenta believes that improving the South American use rate is a key indicator.

The final results for the production plans Syngenta developed and implemented during the calendar year 2001 will not be available until late spring or early summer of 2002 when it has its final sales figures. Syngenta estimates, however, that using the model to help plan 2001 production will increase margins by several million dollars.

Senior managers in Syngenta have stated that, although the margin improvements are very beneficial, the major benefits of the model and its implementation lie elsewhere. Specifically, senior managers think the major benefits are

—The different thought process driving improvements in forecasting demand that have reduced the systematic bias in demand forecasts,

—The opportunity to reduce working capital while still meeting customer needs, and

—The recognition that using modeling helps them to be proactive in developing planning tools in a changing business environment.

One major benefit is the reduction in forecasting bias. In comparing the normalized demand distributions for 1998–1999 and 2000–2001, we found that the forecasts overestimated demand 73 percent of the time

in 1998–1999 and only 59 percent of the time in 2000–2001 (Figure 3). The ideal number is 50 percent.

Syngenta's business is changing. Customers are increasingly demanding a wider variety of multiple seed treatments (fungicide, pesticide, and so forth) on multiple hybrids. Research on genetically modified organisms (GMOs) has led to new varieties that resist depredation from the dreaded European corn borer, tolerate applications of Roundup herbicide, and tolerate corn root worm. These new genetic varieties and combinations and the growing number of possible

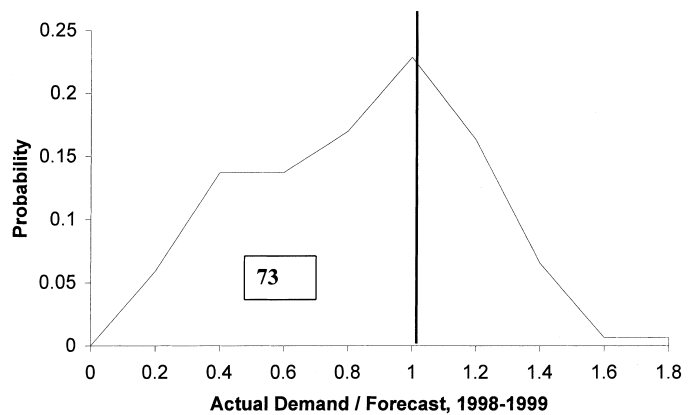


Figure 3a: An analysis of actual demand versus forecast for seed corn using 1998 and 1999 data revealed that 73 percent of the time, actual demand fell short of forecast.

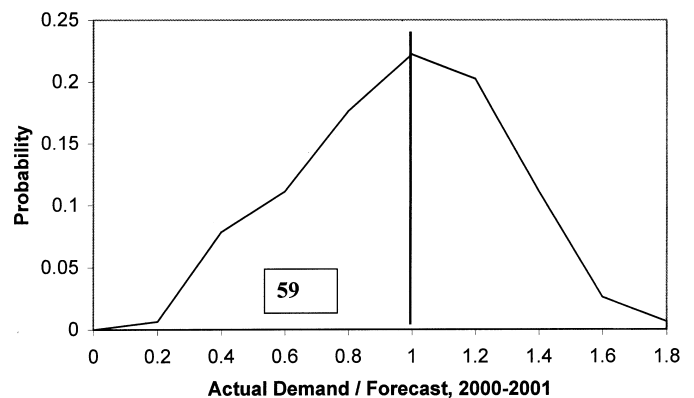


Figure 3b: After experience with the model, Syngenta found that actual demand (2000–2001 seed-corn data) fell short of forecast only 59 percent of the time.

seed coatings imply an explosion in the number of end products. This growth in the number of end products will increase demand uncertainty at the stock-keeping-unit (SKU) level. Syngenta cannot delay customization (via GMO type) until it has resolved demand uncertainties because it must produce the seed corn it sells for one growing season in a previous growing season. Although theoretically it can delay customization (via seed-coating type), doing so would necessitate making huge investments in treating equipment to be able to treat seeds rapidly enough to provide an acceptably short lead time to customers.

To meet such customer demands in a fairly flat sales market without making unacceptably high investments in working capital, Syngenta will need better planning processes than it has previously used. We are working to develop tools to help plan production in this increasingly challenging environment. Syngenta also needs production-planning tools for other seed products, such as soybeans. We are trying to develop production-planning models for these products as well. According to Ed Shonsey, president of Syngenta Seeds, North America,

The efforts associated with developing the model and the use of the derived analysis tool have already paid huge benefits to our company. They have changed the way we think about uncertainty and risk and have forced us to rethink the way we do business. I am convinced that the use of the model and similar decision-support tools will assist us in being successful in the future.

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Executive summaries of Edelman award papers are presented here. The complete article was published in the INFORMS journal *Interfaces* [2003, 33:1, 80-90]. Full text is available by subscription at <http://www.extenza-eps.com/extenza/contentviewing/viewJournal.do?journalId=5>