ECONOMIC ANALYSIS OF PIX (*MEPIQUAT CHLORIDE*) APPLICATION STRATEGIES USING A COTTON SIMULATION MODEL

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Abstract

This paper evaluates the profitability of using different pix application strategies in cotton production in Mississippi. The GOSSYM-COMAX simulation model was used to simulate single and multiple pix application strategies under three different weather scenarios and two soil types. An economic component was developed and integrated into the GOSSYM-COMAX simulation program to determine immediately the economic consequences of different management decisions.

Our results indicate that a single application strategy is superior to multiple applications. Simulated yields using single application were consistently higher than those using multiple applications. Under the normal and hot weather scenarios, the maximum yields were attained with a single application of 24 oz per acre on June 10. Under the cold weather scenario, a single application of 16 oz per acre on June 10 yielded the highest. As multiple applications yielded less and costed more to apply, they were not economical.

The results of economic analysis indicated that, using a single application strategy of 16 oz per acre on June 10, the grower would expect to receive the largest net returns under the normal and cold weather scenarios. Under the hot weather scenario, the grower would expect to receive the largest net return using a single application strategy of 24 oz per acre on June 10. The largest overall expected net return across all weather scenarios would be a single application strategy of 16 oz per acre on June 10. This conclusion is similar to the ones drawn from the simulated yields because the cost differences among different strategies were relatively small.

Introduction

Cotton is the most important source of textile fiber in the world. It accounts for almost one half of the world's total fiber production and the Mississippi Delta States produce almost 40 percent of the total U.S. cotton production (Glade, et al., 1996).

One of the major problems cotton growers in the Delta States face is insect infestation and boll weathering. Such incidences are often accompanied by a late maturing cotton crop. To overcome these problems, cotton growers throughout the cotton belt use pix (mepiquat chloride), a plant growth regulator, to promote early crop maturity. An early cotton crop decreases the likelihood of these incidences. Cotton bolls set by early August are less attractive to the tobacco budworm (Coburn, 1994) and also tends to be less rank and leafy than a late crop, thus allowing for greater ease of defoliation (Cathey et al., 1986). Finally, an early cotton crop often leads to a timely harvest that escapes severe boll weathering damage from late-season rainfall events (Williford, 1992). Pix also controls excessive plant growth by decreasing plant height, number of main stem and branch nodes, branch length, and leaf area; and enhance uniform crop maturity resulting from greater boll (fruit) retention on the lower fruiting branches of the cotton plant (Reddy et al., 1992; Weir, 1993; York et al., 1983).

Many studies have been conducted to determine the optimum timings and rates of pix applications since it was first used commercially in California in 1981 (Hake, et al.,1996). However, most previous studies on pix were focused on the physiological effects such as yield, plant height, leaf area index, the maturity date, etc., and seldom compared profitability resulting from using different pix application strategies. Growers need to know more than just maximum yields. They want to know the economic consequences of each decision they make. Building an economic component and integrating it with a cotton simulation model will enable growers to determine the economic consequence of their decisions.

In our previous study (Watkins et al., 1998), we evaluated economic returns of 12 pix application strategies under different soils and weather scenarios. In that study, method and amount of nitrogen applications and irrigation were held constant across all soil types and weather scenarios. Since effectiveness of pix application depends on proper nitrogen and irrigation management, pix management strategy should focus on the optimization of water and nitrogen inputs (Scientific Software Solutions, 1997). If the plant is stressed by water or nitrogen deficiency, pix application will not improve yields. In this study, we evaluate the economic returns of different pix application strategies considering the interactions of nitrogen fertilizer applications and irrigation. The GOSSYM-COMAX simulation model is used to simulate alternative pix application strategies under three different weather scenarios and two soil types. The expert system component of the simulation program(COMAX) was used to simulate nitrogen fertilizer application and irrigation when the nitrogen and water stress levels exceed a prescribed level so that plants will subject to less nitrogen and water stresses.

The Simulation Model

Ideally, long-term experiments should be conducted to compare the profitability of different pix application strategies. However, field experiments are expensive and time-consuming. Simulation models offer the potential to conduct controlled, computerized experiments by replicating natural conditions that could otherwise not be replicated, or could be replicated only at great cost (Swinton and Black, 2000).

The GOSSYM-COMAX cotton management system is a system that applies computer simulation and artificial intelligence techniques to the problem of making management decisions during the production of cotton. It is a process-oriented, physiological model based on physiology and physics of the soil-plant-atmospheric system (Reddy, et al., 1990). GOSSYM-COMAX has been used by cotton growers throughout the cotton belt for several years. It simulates physiological effects of different management strategies on first square, first bloom, water stress, nitrogen stress, number of nodes, leaf area index, squares per acre, green bolls per acre, open bolls per acre, earliness, plant height, and yields.

The system is composed of two parts: GOSSYM, which simulates cotton growth and development, and COMAX, an expert system which advises management decisions (Scientific Software Solutions, 1997). This system helps growers make decisions concerning the best irrigation management, nitrogen management, pix applications, and crop termination to maximize lint yields, but it does not provide growers with economic return analysis.

The inputs required to run GOSSYM-COMAX include weather (daily solar radiation, maximum and minimum air temperature, rainfall, and wind speed), irrigation water, nitrogen fertilizer application, initial soil properties, hydraulic properties of the soil, plant population, row spacing, latitude of the site, etc. In this study, the 1992 actual weather in Stoneville, Mississippi, was used as normal weather and the cold and hot weather scenarios were constructed by subtracting or adding 2 degrees from the normal weather, respectively. We used GOSSYM with an economic component to simulate dryland cotton production in the Mississippi and evaluate the economic returns of different pix application strategies under two soil types and three weather scenarios.

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Cotton Management Practices

Planting date is critical for early fruit set, establish strong fruit retention, and make the most of the primary fruiting cycle. Optimal planting date depends on weather scenarios. If planted too early, the crop may experience cold weather stress resulting in lower yields. If planted too late, the crop may become too vegetative and difficult to manage, resulting lower yields (Smith and Cothren, 1999).

Cotton growers in Mississippi Delta favor crop earliness for insect management consideration because a late maturing crop is vulnerable to high insect pressure and high incidence of boll weathering (Watkins, et al.). Planting date varies from April 15 to June 3 but most growers plant their cotton between April 25 and May 25 and harvest between the last week of September to the last week of November, depending on weather. In this study, we assume that cotton growers use the variety DES 119 and plant around April 28 with emergence on May 5. Cotton is grown in 38 inch row spacing, the conventional row spacings for cotton in the Mississippi delta, with 8-row equipment. The latitude is set to 34^0. The plant density is set to 42,843 plants per acre. Two hundred pounds of fertilizer ensol are sidedressed before planting and 15 lb of nitrogen fertilizer is applied every 7 days when the simulated nitrogen stress level is less than 0.75 (1 being no stress) and less than 60 percent of bolls are open. Whenever the simulated water stress level for the plant is below 0.75 (1 being no stress), 1.25 inches of irrigation water is applied using center pivot spray.

There are a wide variety of soils in the Mississippi delta. The most productive soils are the Bosket sandy loam and the Beulah loamy fine sand soils. However, the most prevalent soils used for cotton production in the Mississippi delta are the Dundee soils and the Forestdale soils (Watkins, et al., 1998). We chose Dundee sandy loam soil and the Bosket soils in this study to show how different soils influence the effectiveness and profitability of pix applications.

Pix Application Strategies

GOSSYM can be used to simulate pix application scenarios with respect to different application rates and timing. Pix can be applied in a single application or in multiple applications over a period of time. To simulate pix application strategies, growers need to specify the rate of applications, the number of applications, the days between applications, and the starting date of application. The starting date can be a calendar date, days after match head square, or days after first bloom (Scientific Software Solutions, 1997).

BASF, the company that developed pix, conducted rate studies during the earlier years of testing throughout the United States. The results indicated the proper rate and timing should be 1.0 pint per acre applied at early bloom (Hake, et al., 1996) In 1982, California initiated pix application rate studies comparing 0.5 and 1.0 pint per acre. The results indicated that the average lint yield per acre was higher for the use of pix at 0.5 pint per acre than at 1 pint per acre. By 1986, the rate of 0.5 pint per acre had become the standard practice in the San Joaquin Valley of California (Hake, et al., 1996).

Many studies indicated low-rate, multiple pix applications were not superior to a single application. In North Carolina, the results of the experiments conducted by Guthrie (1989) showed that low-rate, multiple applications were not superior to the single application of 0.5 pint per acre applied at early bloom. The results from Weir and Kerby's (1990) studies from 1987 to 1989 in California and Australia also indicated that multiple applications were not superior to the single application of 0.5 pint per acre applied at early bloom. However, low-rate, multiple applications offered some advantage in some tests where cotton was grown in 30-inch row spacing (Hake, et al., 1996).

In this study, we compare the baseline strategy (S0000), where no pix is applied, with the following single and multiple pix application strategies with different rates and timings:

Single Applications

S610L–Single application on June 10 at 8 oz per acre
S610M–Single application on June 10 at 16 oz per acre.
S610H–Single application on June 10 at 24 oz per acre.

S620L–Single application on June 20 at 8 oz per acre.
S620M–Single application on June 20 at 16 oz per acre.
S620H–Single application on June 20 at 24 oz per acre.

S630L–Single application on June 30 at 8 oz per acre.
S630M–Single application on June 30 at 16 oz per acre.
S630H–Single application on June 30 at 24 oz per acre.

S710L–Single application on July 10 at 8 oz per acre.
S710M–Single application on July 10 at 16 oz per acre.
S710H–Single application on July 10 at 24 oz per acre.

S720L–Single application on July 20 at 8 oz per acre.
S720M–Single application on July 20 at 16 oz per acre.
S720H–Single application on July 20 at 24 oz per acre.

S730L–Single application on July 30 at 8 oz per acre.
S730M–Single application on July 30 at 16 oz per acre.
S730H–Single application on July 30 at 24 oz per acre.

Multiple Applications

M610R05–4 applications at 0.5 oz per acre beginning on June 10 in 10-day intervals.
M610R10–4 applications at 1.0 oz per acre beginning on June 10 in 10-day intervals.
M610R20–4 applications at 2.0 oz per acre beginning on June 10 in 10-day intervals.
M610R30–4 applications at 3.0 oz per acre beginning on June 10 in 10-day intervals.
M610R40–4 applications at 4.0 oz per acre beginning on June 10 in 10-day intervals.

M620R05–4 applications at 0.5 oz per acre beginning on June 20 in 10-day intervals.
M620R10–4 applications at 1.0 oz per acre beginning on June 20 in 10-day intervals.
M620R20–4 applications at 2.0 oz per acre beginning on June 20 in 10-day intervals.
M620R30–4 applications at 3.0 oz per acre beginning on June 20 in 10-day intervals.
M620R40–4 applications at 4.0 oz per acre beginning on June 20 in 10-day intervals.

M630R05–4 applications at 0.5 oz per acre beginning on June 30 in 10-day intervals.
M630R10–4 applications at 1.0 oz per acre beginning on June 30 in 10-day intervals.
M630R20–4 applications at 2.0 oz per acre beginning on June 30 in 10-day intervals.
M630R30–4 applications at 3.0 oz per acre beginning on June 30 in 10-day intervals.
M630R40–4 applications at 4.0 oz per acre beginning on June 30 in 10-day intervals.

Simulation Results

The simulation results for a single pix application are shown in Table 1 and multiple applications on Table 2. Our results confirmed results in the literature that a single application strategy is superior to multiple applications. The yields using single application are consistently higher than those using multiple applications under all pix application strategies. Since multiple applications yield less and cost more to apply, they are not economical. Thus, they will be excluded from our economic analysis.

For a single pix application, under the normal and hot weather scenarios, maximum yields are attained with strategy S610H, followed by S610M. Under the cold weather scenario, S610M yielded the highest. Since the yield differences between S610H and S610M are not significant, it appears that S610M (one application of 1 pint of pix applied on June 10) is the optimal strategy. Our results also showed that when pix is applied very late (say July 20 and July 30), it has little effect on plant height, maturity rate, and the yields. This simulation result is almost the same as the one with no pix.

Since we applied nitrogen and irrigation whenever the plants were stressed, soil types had no effect on yield, plant height, or maturity. In fact, our simulated results for Dundee and Bosket soils are almost identical. Thus, only the results using Dundee soil are presented.

Yields under the cold weather scenario were consistently higher than those under the normal and hot weather scenarios. The reason is that during the cold weather, plants have less respiration, less water stress, and longer boll filling period due to the lower temperature, resulting in increased boll size and higher yields.

One of the main purposes of pix applications is to control excessive plant growth and to enhance early crop maturity so as to reduce the incidence of boll weathering and insect pressure. As shown in Table 1, the plant height has been reduced from 52.4 to 40.3, 53.9 to 40.1, and 49.7 to 38.3 inches under the normal, hot, and, cold weather scenarios, respectively, when the strategy S610M is used. But the pix application didn't enhance maturity. In some cases, cotton crops with pix applications delayed maturity, mostly due to the plants retained few bolls which otherwise would have been aborted. This resulted in delayed maturity date of up to a week.

Economic Analysis

Cotton production costs are derived from Cotton 2000 Planning Budgets by Mississippi Agricultural and Forestry Experiment Station (1999). Variable costs include spray, fertilizers, fungicides, herbicides, insecticides, seeds, technology fees, growth regulators, service fees, adjuvants, custom fertilizer/ lime applications, harvest aids, custom harvest and haul, labor (operator and hand), irrigation, fuel, repair and maintenance, and interest on operating capital. Fertilizer, fungicide, herbicide, and insecticide costs represent the amounts typically used in the Mississippi delta states. Input prices were adjusted as necessary to reflect changes since the publication of the budget. Unallocated labor or overhead labor accounts for labor expenses that are not directly related to fieldwork and is estimated at 80 percent of the operator labor (Spurlock and Gillis. 1997).

Net returns above variable costs were used to compare profitability of different pix applications. Net returns were calculated as the difference between total returns and variable costs with the total returns including sales of cotton lint and cotton seed.

Fixed costs were not included in the calculation because they are the same for all strategies. Cotton seed yields were obtained by multiplying lint yields by the factor of 1.55, the proportion of seed yield to lint yield used in the Cotton 2000 Budget. The lint price was obtained by averaging prices received by upland producers from July to September, 2000, in the October 2000 issue of Cotton and Wool Outlook. The seed price of 5 cents per lb was obtained from the Cotton Budget.

Table 3 shows the net returns for different pix application strategies under three different weather scenarios. The last column shows the overall expected net return across all weather scenarios for each pix application strategy, assuming that the probabilities for having a normal, hot, and cold weather scenarios are 0.53, 0.20, and 0.27, respectively, for a given year (Watkins, et al., 1998).

These results indicate that if no pix is applied, the grower would expect to receive net returns of $111.50, $25.38, and $102.88 per acre, under normal, hot, and cold weather scenarios, respectively, with an overall average expected net returns of $91.94 across all weather scenarios. The cotton grower using the strategy S610M would expect to receive the largest net returns of $154.97 and 165.52, under the normal and cold weather scenarios, respectively. Under the hot weather scenario, the grower would expect to receive the largest net return of $49.00, using the strategy S610H. The largest overall expected net return across all weather scenarios would be $135.97 using the strategy S610M. This result is consistent with the results obtained from the simulated yields because the cost differences among different strategies are small.

Summary and Conclusions

This study evaluated the economic returns of using different pix application strategies in cotton production in Mississippi. The GOSSYM-COMAX simulation model was used to simulate single and multiple pix application strategies under three different weather scenarios and two soil types. An economic component was developed and integrated with the GOSSYM-COMAX simulation program to determine the economic consequences of different management decisions.

We assume that the variety DES 119 of cotton was planted on Dundee sandy loam soil and the Bosket soil. Since pix is not effective if plants have nitrogen or water stresses, the expert system component of the model automatically apply nitrogen fertilizers or irrigation whenever the nitrogen or water stress levels exceeded a prescribed level. With little nitrogen and water stresses, soil types have no effect on the effectiveness of pix. In fact, our simulated results for Dundee and Bosket soils are almost identical. Thus, only the results using Dundee soil are presented.

Our results indicate that single application strategy is superior to multiple applications. The yields using single application are consistently higher than those using multiple applications. Under the normal and hot weather scenarios, the maximum yields are attained with strategy S610H, closely followed by S610M. Under the cold weather scenario, S610M yielded the highest. Since the yield differences between S610H and S610M are not significant, it appears that S610M (one application of 1 pint of pix applied on June 10) is the optimal strategy. As multiple applications yielded less and costed more to apply, they were not economical. Thus, they were excluded from economic analysis.

The results of economic analysis was similar to those of yield analysis. If no pix is applied, the grower would expect to receive net returns of $111.50, $25.38, and $102.88, under normal, hot, and cold weather scenarios, respectively, with an overall average expected net returns of $91.94 across all weather scenarios. Using the strategy S610M, the grower would expect to receive the largest net returns, $154.97 and 165.52, under the normal and cold weather scenarios, respectively. Under the hot weather scenario, the grower would expect to receive the largest net return of $49.00 using the strategy S610H. The largest overall expected net return across all weather scenarios would be $135.97 using the strategy S610M. This conclusion is similar to the ones drawn from the simulated yields because the cost differences among different strategies relatively small.

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Table 1. Simulated yields, plant heights, and maturity dates for Dundee soil using a single pix application.

	Yield (bale)			Plant Height (inch)			Maturity Date		
Strategy	**Normal**	**Hot**	**Cold**	**Normal**	**Hot**	**Cold**	**Normal**	**Hot**	**Cold**
S0000	2.00	1.99	2.05	52.4	53.9	49.7	19-Aug	16-Aug	29-Aug
S610L	2.12	2.06	2.27	47.0	47.0	44.8	22-Aug	19-Aug	2-Sep
S610M	2.20	2.18	2.34	40.3	40.1	38.3	24-Aug	19-Aug	2-Sep
S610H	2.22	2.19	2.24	37.3	38.5	34.8	25-Aug	22-Aug	2-Sep
S620L	2.06	1.97	2.17	48.5	47.2	45.1	22-Aug	15-Aug	30-Aug
S620M	2.04	2.00	2.17	48.9	47.6	43.9	22-Aug	17-Aug	1-Sep
S620H	2.02	2.05	2.21	44.5	45.0	41.1	22-Aug	18-Aug	1-Sep
S630L	2.01	1.94	2.04	52.8	50.7	48.3	19-Aug	16-Aug	29-Aug
S630M	2.00	1.96	2.04	50.4	47.8	50.2	22-Aug	15-Aug	30-Aug
S630H	1.98	1.93	2.01	50.9	48.5	48.9	22-Aug	15-Aug	29-Aug
S710L	2.03	1.93	2.05	50.6	49.2	48.5	22-Aug	16-Aug	30-Aug
S710M	2.02	1.93	1.97	53.0	50.3	49.9	19-Aug	16-Aug	28-Aug
S710H	1.99	1.93	2.01	52.9	52.7	48.9	20-Aug	16-Aug	29-Aug
S720L	2.00	1.99	2.07	52.1	54.0	49.4	19-Aug	16-Aug	30-Aug
S720M	2.00	1.98	2.05	51.9	54.0	50.9	19-Aug	16-Aug	30-Aug
S720H	2.00	1.98	2.05	51.9	54.0	50.9	19-Aug	16-Aug	30-Aug
S730L	2.00	1.99	2.05	52.1	54.0	49.5	19-Aug	16-Aug	29-Aug
S730M	2.00	1.98	2.04	51.9	54.0	47.9	19-Aug	16-Aug	29-Aug
S730H	2.00	1.98	2.04	51.9	54.0	47.9	19-Aug	16-Aug	30-Aug

Table 2. Simulated yields, plant heights, and maturity dates for Dundee soil using multiple pix applications.

	Yield (bale)			Plant Height (inch)			Maturity Date		
Strategy	**Normal**	**Hot**	**Cold**	**Normal**	**Hot**	**Cold**	**Normal**	**Hot**	**Cold**
M610R05	2.02	1.94	2.04	51.7	49.0	48.4	19-Aug	16-Aug	30-Aug
M610R10	2.07	1.97	1.96	51.4	50.1	50.6	22-Aug	16-Aug	27-Aug
M610R20	2.07	1.96	2.16	50.3	50.0	47.1	22-Aug	16-Aug	30-Aug
M610R30	2.07	1.98	2.14	49.0	48.0	47.4	22-Aug	17-Aug	30-Aug
M610R40	2.05	2.00	2.20	49.2	48.0	44.1	22-Aug	18-Aug	2-Sep
M620R05	2.05	1.92	2.09	50.8	49.2	49.2	22-Aug	16-Aug	30-Aug
M620R10	2.03	1.94	2.03	51.7	49.0	48.5	19-Aug	16-Aug	30-Aug
M620R20	2.06	1.96	1.96	51.5	50.3	50.0	22-Aug	16-Aug	28-Aug
M620R30	2.04	1.94	1.99	51.0	50.8	49.3	22-Aug	16-Aug	28-Aug
M620R40	2.04	1.93	2.13	50.8	49.8	47.1	22-Aug	16-Aug	30-Aug
M630R05	2.01	2.01	2.06	52.4	54.2	49.4	19-Aug	16-Aug	29-Aug
M630R10	2.04	1.99	2.09	50.8	53.7	49.3	22-Aug	16-Aug	30-Aug
M630R20	2.03	1.92	1.96	50.6	49.2	50.2	22-Aug	16-Aug	28-Aug
M630R30	2.01	1.93	2.05	53.1	52.0	50.0	19-Aug	16-Aug	30-Aug
M630R40	2.06	1.92	2.04	53.5	51.8	48.6	22-Aug	16-Aug	30-Aug

Table 3. Net returns by pix strategy and weather scenario.

Pix strategy	Net Return ($)			
	Normal	Hot	Cold	Expected
S0000	111.50	25.38	102.86	91.94
S610L	135.45	30.43	159.53	120.95
S610M	154.97	45.75	165.52	135.97
S610H	153.96	49.00	143.67	130.19
S620L	120.47	19.20	142.99	106.30
S620M	109.48	34.93	131.19	100.43
S620H	104.04	51.50	128.76	100.20
S630L	107.99	21.07	109.14	90.92
S630M	99.50	32.44	100.61	86.39
S630H	88.50	33.19	92.56	78.54
S710L	112.98	14.83	110.76	92.75
S710M	104.49	21.21	91.56	84.34
S710H	91.00	31.32	93.96	79.86
S720L	105.50	29.88	104.47	90.10
S720M	99.50	31.88	97.98	85.56
S720H	93.50	36.38	94.60	82.37
S730L	105.50	29.88	99.48	88.75
S730M	99.50	31.88	101.03	86.39
S730H	93.50	36.38	97.66	83.20