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# PHYSIOLOGY

## Pima Cotton Growth and Yield Responses to Late-Season Applications of Mepiquat Chloride

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### INTERPRETIVE SUMMARY

Pima cotton acreage has continued to increase in the San Joaquin Valley of California since the recent identification of cultivars that perform well under local conditions. As a result of the expanding acreage (currently 185,000 acres) there is an increased need for managing both the vegetative and reproductive growth to improve crop quality and yield. Early guidelines for mepiquat chloride (PIX) usage were based on California Acala cotton guidelines and previous experiences in Arizona in growing cultivars similar to those grown in the San Joaquin Valley.

Earlier studies conducted in the 1991 and 1992 seasons (Munk et al., 1997) suggested that, although PIX can modify vegetative growth, no yield improvements from early (first-bloom) applications were identified in any of the examined treatments. Beginning in 1993, a series of studies were conducted in the San Joaquin Valley to identify potentialbenefits for California Pima cotton production systems of late-season PIX applications. During the 1993 to 1996 seasons, PIX-Pima trials with application timing ranging from first bloom to 28 days following first bloom were established at 14 locations. The experimental treatments were dominated by two sequential applications, the first applied at 14 days after first bloom and the second application made at 10 to 14 days after the first application. The application rates were also varied.

Plant growth data suggest that, in most instances, significant reductions in plant height result from sequential applications of PIX. Increases in the application rate above a total of 1 pint per acre did not show increased growth suppression. PIX application rates of up to 1 pint per acre could, therefore, be justified for controlling excessive vegetative growth.

Fruit retention rates for these same trials were inconsistent when PIX-treatment data were compared to untreated cotton. Plants subjected to lower sequential rate applications of PIX showed a tendency toward increases in bottom fruit retention at the end of the season. The higher fruit retention observed after these treatments may be related to the lower number of fruiting branches that constituted the 95% zone for first-position fruit and related earlier crop cutout.

Yield levels from these trials were mixed; some PIX treatments resulted both in statistically significant increases and decreases in yield, depending on year and location. No variable was consistently correlated with these differences. Numeric averages of yield over all locations showed that two applications of one-half pint per acre resulted in the highest average yield. Although statistical significance was found in few individual fields, an average lint increase of 54 pounds per acre was achieved across all studies with this treatment rate.

Yield improvements with PIX in Pima cotton can be quite substantial in some situations. However, this optimism should be tempered by the observation that these responses are not yet as predictable as those observed for Acala cotton. Also, under current management practices, PIX applications may occasionally lead to reduced productivity. Linkages between crop growth and development, field agronomic characteristics, and potential plant stressors (water and heat) continue to be explored in the evaluation of PIX responses to Pima. However,

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no proposed linkages have been supported by the data received thus far. We suggest that Pima cotton, compared to Acala cottons, responds more positively to later applications of PIX due to the delayed shifting of the plants, and therefore resource partitioning, from vegetative to reproductive growth. This seems a reasonable hypothesis since the proportion of yield set late in the season is much larger in Pima than in Acala cotton varieties.

## ABSTRACT

**Studies were conducted in the San Joaquin Valley of California to evaluate the rate and timing responses of Pima cotton (*Gossypium barbadense*) to mepiquat chloride (PIX). Preliminary data collected in 1991 and 1992 indicate that applications made at early bloom are not economical and can occasionally result in a yield decline. Late-season applications, however, tended to have more positive yield results. Best overall yields came from mid- and late-bloom sequential applications of PIX at a rate 0.025 kg a.i. ha$^{-1}$, applied at 14 days following first bloom and again at 10 to 14 days following the first application. Fourteen independent studies, occurring over a 4-year period, showed an average yield response that exceeded 60 kg ha$^{-1}$, although, in most cases, these effects were not statistically significant (*P* = 0.05).**

During the 1980s, it became apparent that the use of PIX in California would play a critical role in achieving earliness and increasing the productivity of Acala cotton (*Gossypium hirsutum*) (Kerby, 1985; Kerby et al., 1986). Extensive research during the 1990s has allowed University of California researchers and others to identify optimum use rate and timing and to develop a predictive model for optimal PIX application on Acala cotton.

Beginning in 1991, the San Joaquin Valley Cotton Board recognized that Pima cotton could be a key genotype for improving regional high quality standards and approved the use of the first Pima genotype in the San Joaquin Valley. Pima S-6, developed in the USDA breeding program in Arizona, became an important Pima variety in California with nearly 12 000 ha of production in Fresno County alone. However, growers found little available information on the best management practices for this new genotype, and the long process of identifying proper practices necessary to obtain high yields under San Joaquin Valley's climatic conditions was begun.

Initially, Arizona Pima management guidelines suggested that PIX could, in fact, be an important tool in the management of growth and increasing yields (Silvertooth et al., 1989, 1990). Early California recommendations were, therefore, tentative and based on both the California Acala cotton guidelines and experience with Pima and PIX in Arizona.

Yield responses to early-season PIX applications on Pima genotypes have been studied in the San Joaquin Valley (Munk et al., 1997). The results of those studies suggested that early-bloom applications of PIX had no positive impact on yields at five separate locations during the 1991 and 1992 seasons. Although statistically significant yield increases were not achieved in those studies, trends toward higher yields were obtained from PIX treatments applied at least 14 days following first bloom, followed by a second application 10 to 14 days following the first application.

As Pima production in California continues to rise (75 000 ha in 1997), PIX guidelines are in increasing demand by the grower community. Therefore, beginning in 1993, a series of studies was conducted in the San Joaquin Valley by University of California farm advisors and specialists to identify the potential benefits in Pima cotton production systems of late-season PIX applications. Based on early observations of the Pima cotton and previous results with multiple applications of PIX on Acala cotton cultivars (Weir and Kerby, 1990), sequential applications of PIX on this more indeterminate cotton genotype were thought to be most valuable. This paper compares the responses to PIX application scheduling of Pima cotton and Acala genotypes and offers suggestions for improving yield benefits through use and timing of PIX applications.

## MATERIALS AND METHODS

During the 1993 to 1996 seasons, PIX Pima trials were carried out in Fresno, Kern, Merced, and Tulare Counties in the San Joaquin Valley. The treatments included multiple applications of PIX applied at several rates from first bloom to 4 weeks following first bloom. During the 1993 season, PIX application rates of 0.037 or 0.049 kg ha$^{-1}$, followed by an application of 0.025 kg ha$^{-1}$ 10 to 14 days later were evaluated. A second set of PIX treatments evaluated consisted of an application of 0.037 kg ha$^{-1}$ or 0.049 kg ha$^{-1}$ 14 days after first bloom and a 0.025 kg ha$^{-1}$ application 14 days following the first application. The multiple-treatment PIX studies in 1994 evaluated 0.025, 0.037, or 0.049 kg ha$^{-1}$ applications, followed 10 to 14 days later by a 0.025 kg ha$^{-1}$ application. The late-season treatments conducted in 1995–1996 called for 0.025 or 0.037 kg ha$^{-1}$ PIX applications 10 to 14 days after first bloom and followed by a second application of 0.025 kg ha$^{-1}$ applied 4 weeks following first bloom. An untreated control was evaluated with the PIX-treated cotton at all sites.

Each test plot was replicated four times using a randomized complete block design on fields ranging from 200 to 400 m. Bed widths of 0.76, 0.96, or 1.02 m were also evaluated in this study. At the University of California's West Side Research Extension Center, 90 m plot lengths were evaluated. Crop evapotranspiration in the San Joaquin Valley ranged from 670 to 740 mm during the 1993–1996 seasons. Crop-irrigation management practices in each field were maintained at water stress levels low enough to minimize the impact of water deficits on yield. All plots were managed for optimal economic returns.

The California industry standard variety, Pima S-7, was evaluated throughout this study. In the San Joaquin Valley, optimal plant density ranges from 94 000 to 156 000 plants per hectare. The crop planting date varied for each trial. However, no fields were selected that were considered to be out of the planting-date range associated with highest production. Crop developmental characteristics were recorded at the time of the first PIX application and again prior to defoliation. Plant heights, fruiting and vegetative node numbers, first-position fruit retention on the early-season plant maps, and fruit retention at all positions on final plant maps in each study were monitored using the California Cotton Manager Program (CCM) and the CaliforniaPlant Mapper (CPM) Program (Munier et al., 1996; Kerby et al., 1996).

Yield estimates were taken from two- or four-row spindle pickers set to evaluate four or eight rows and run the length of the field for each plot. Gin turnout estimates were obtained from the average of two 2.5 kg subsamples taken from each treatment at the time of harvest.

## RESULTS

Plant growth and performance results from this series of trials were mixed. Some plant growth parameters were consistently modified by PIX applications, and others showed no apparent effect. As reported in earlier tests with Acala cotton cultivars (Weir and Kerby, 1990), reductions in plant height were generally observed within 7 to 14 days following PIX application in these Pima studies. For example, in late-season sequential trials in the 1995 and 1996 trials, a plant height reduction of 5 to 13 cm was observed with multiple PIX applications (Table 1). The lower rate of 0.024 kg ha$^{-1}$, applied twice, caused no significant difference in height, in comparison with the higher rate treatments, including the 0.096 kg ha$^{-1}$ treatment. Total rates of up to 0.059 kg ha$^{-1}$ could, therefore, be justified for controlling vegetative growth. All of the PIX treatments applied, with the exception of treatment 3 in Table 1, were significant ($P$ = 0.05).

**Table 1. Plant heights at three locations in the 1995 and 1996 Pix-Pima University of California studies.**

| | Application rate | | | Plant height | | | |
|---|---|---|---|---|---|---|---|
| Treatment | 14 d after first bloom | 10–14 d after first application | Cutout | Fresno 96 | Tulare 96 | Merced 95 | Mean |
| | kg a.i. ha$^{-1}$ | | | cm | | | |
| Untreated | -- | -- | -- | 110.7 | 95.8 | 79.0 | 95.3a† |
| PIX | 0.025 | 0.025 | -- | 82.0 | 85.9 | 77.0 | 81.5b |
| PIX | 0.037 | 0.025 | -- | 98.3 | 95.3 | 78.5 | 90.7ab |
| PIX | 0.037 | 0.037 | -- | 88.1 | 94.5 | 71.6 | 84.6b |
| PIX | 0.037 | 0.049 | -- | 86.9 | 89.7 | 70.9 | 82.6b |
| PIX | 0.037 | 0.037 | 0.025 | 86.6 | 90.2 | 79.2 | 85.3ab |
| LSD 0.05 = 9.89 | | | | | | | |
| CV = 6.27% | | | | | | | |

† **Means followed by same number are not significantly different ($P$ = 0.05).**

**Table 2. Retention of first-position (FP1) bolls in the bottom five fruiting branches (FB) in 1995 and 1996 Univ. of California Pix-Pima studies.**

| | Application rate | | | Percent FP1 retention in bottom five FB | | | | |
|---|---|---|---|---|---|---|---|---|
| Treatment | 14 d after first bloom | 10–14 d after first application | Cutout | Fresno 96 | Tulare 96 | Merced 95 | Mean | |
| | ---------------------kg a.i. ha$^{-1}$ | -------------------------- | | | | | | |
| Untreated | -- | -- | -- | 51.0 | 79.0 | 78.0 | 69.3 | NS† |
| PIX | 0.025 | 0.025 | -- | 64.0 | 68.0 | 82.5 | 71.5 | NS |
| PIX | 0.037 | 0.025 | -- | 63.0 | 76.0 | 81.1 | 73.4 | NS |
| PIX | 0.037 | 0.037 | -- | 58.0 | 69.0 | 81.7 | 69.6 | NS |
| PIX | 0.037 | 0.049 | -- | 50.0 | 72.0 | 75.8 | 65.9 | NS |
| PIX | 0.037 | 0.037 | 0.025 | 62.0 | 61.0 | 84.1 | 69.0 | NS |
| LSD 0.05 = 10.7 | | | | | | | | |
| CV = 8.42% | | | | | | | | |

**† NS = Nonsignificant (*P* = 0.05).**

**Table 3. First-position bolls retained in the 95% zone in the 1995 and 1996 University of California Pix-Pima studies. The 95% zone is defined as the number of fruiting branches that contribute to 95% of the total boll number.**

| | Application rate | | | 95% Zone (FP1 bolls) | | | |
|---|---|---|---|---|---|---|---|
| Treatment | 14 d after first bloom | 10–14 d after first application | Cutout | Fresno 96 | Tulare 96 | Merced 95 | Mean |
| | -----------------------kg a.i. ha$^{-1}$ | ---------------------------- | | | | | |
| Untreated | -- | -- | -- | 17.3 | 13.0 | 10.4 | 13.6a† |
| PIX | 0.025 | 0.025 | -- | 15.8 | 12.0 | 9.4 | 12.4b |
| PIX | 0.037 | 0.025 | -- | 17.4 | 13.0 | 10.3 | 13.6a |
| PIX | 0.037 | 0.037 | -- | 17.0 | 14.0 | 9.7 | 13.6a |
| PIX | 0.037 | 0.049 | -- | 16.3 | 14.0 | 10.5 | 13.6a |
| PIX | 0.037 | 0.037 | 0.025 | 16.1 | 13.0 | 10.8 | 13..3ab |
| LSD 0.05 = 1.02 | | | | | | | |
| CV = 4.21% | | | | | | | |

**† Means followed by same number are not significantly different (*P* = 0.05).**

In these trials, retention of the bottom five first-position fruits was inconsistent in PIX-treated cotton, compared to the untreated controls (Table 2). Plants subjected to lighter PIX applications (0.060 kg ha$^{-1}$) tended to retain more fruits in first position on the lower five fruiting nodes near the end of the season. However, the final plant maps did reveal some differences in the number of total fruiting branches that composed the 95% zone for first position fruits. The only treatment that resulted in a significantly lower number of fruiting branches was the low-rate treatment 2 of Table 2. That treatment consistently resulted in fewer yield-contributing fruiting branches. This effect may result from the slightly higher first-position boll retention in the lowest five fruiting nodes, an effect observed for this treatment (Table 3). Such increased boll retention low in the plant would result in this treatment inducing earlier plant cutout.

During the 1993 season, plant growth responses in this set of trials were similar to those described in Table 1, and the 1993 reductions in plant height ranged from 3 to 8 cm. Yields at the Fresno and West Side Research and Extension Centers were consistently improved by the two season PIX treatments; and, overall, PIX treatments improved yields by an average of 78 kg lint per hectare (Table 4). The application-timing data suggested that continued investigations of PIX-Pima interactions were needed, and subsequent experimental designs were expanded to include late (post-bloom) applications of PIX at rates higher than those recommended for Acala cottons.

As in the 1993 trials, 1994 yield data from all test locations showed upward trends following PIX applications, and lint yields from the Fresno County trial were significantly higher for all application rates except for the 0.074 kg ha$^{-1}$ early treatment. Overall, PIX applications in 1994 increased average

**Table 4. Lint yields from three San Joaquin Valley locations in 1993.**

| Treatment | Application rate | | | Yield | | | |
|---|---|---|---|---|---|---|---|
| | 14 d after first bloom | 2-3 wk after first bloom | First bloom | Fresno | Merced | WSREC | Mean |
| | kg a.i. ha$^{-1}$ | | | kg ha$^{-1}$ | | | |
| Untreated | -- | -- | -- | 1200 | 2184 | 1612 | 1666 |
| PIX | 0.037 | 0.025 | -- | 1196 | 2406 | 1658 | 1753 |
| PIX | -- | 0.037 | 0.025 | 1236 | 2258 | 1711 | 1735 |
| PIX | 0.049 | 0.025 | -- | 1179 | 2302 | 1731 | 1737 |
| PIX | -- | 0.049 | 0.025 | 1263 | 2286 | 1706 | 1752 |
| LSD 0.05 | | | | NS† | NS | NS | |
| CV, % | | | | 5.70 | 2.90 | 5.76 | |

† NS = Nonsignificant (*P* = 0.05).

**Table 5. Lint yields from five San Joaquin Valley locations in 1994.**

| Treatment | Application rate | | Yield | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2-3 wk after first bloom | First bloom | Fresno | Kern | Tulare | Merced | WSREC | Mean |
| | kg a.i. ha$^{-1}$ | | kg ha$^{-1}$ | | | | | |
| Untreated | -- | -- | 1068 | 1446 | 939 | 1439 | 1771 | 1333 |
| PIX | 0.025 | 0.025 | 1169 | 1479 | 1011 | 1713 | 1881 | 1450 |
| PIX | 0.037 | 0.025 | 1159 | 1513 | 991 | 1524 | 1898 | 1417 |
| PIX | 0.049 | 0.025 | 1161 | 1502 | 925 | 1551 | 1843 | 1397 |
| PIX | 0.049 | -- | 1121 | 1435 | -- | 1612 | 1905 | 1411 |
| LSD 0.05 | | | 85.3 | NS† | NS | NS | NS | |
| CV, % | | | 5.46 | -- | 7.10 | 13.50 | 3.90 | |

† NS = Nonsignificant (*P* = 0.05).

productivity by 86 kg lint per hectare. Although statistical significance at the *P* = 0.05 level was observed at the Fresno site only, the treatment having the greatest yield impact over all sites was the treatment consisting of the 0.025 kg ha$^{-1}$ PIX application at full bloom followed by 0.025 kg ha$^{-1}$ PIX applied 14 days later (Table 5). This treatment resulted in an increase of 118 kg lint ha$^{-1}$ over the untreated control. Yield data from one 1995 trial conducted in Fresno County did not show yield benefits from PIX application (Table 6).

**Table 6. Lint yields in 1995 from Fresno location in the San Joaquin Valley.**

| Treatment | Application rate | | | Yield |
|---|---|---|---|---|
| | First bloom | 14 d following first bloom | 10-14 d after first application | |
| | kg a.i. ha$^{-1}$ | | | kg ha$^{-1}$ |
| Untreated | -- | -- | -- | 1637 |
| PIX | 0.025 | 0.025 | -- | 1599 |
| PIX | -- | 0.037 | -- | 1459 |
| PIX | -- | 0.037 | 0.049 | 1586 |
| PIX | -- | 0.099 | -- | 1562 |
| LSD 0.05 | | | | 140.7 |
| CV, % | | | | 6.53 |

Yields from the 1995 and 1996 trials were mixed (Table 7), and the Tulare County site only showed statistically significant yield reductions after the high rate treatment of 0.037 kg ha$^{-1}$ at full bloom, plus the same rate of application at full bloom 10 to 14 days later and again at cutout. Throughout this study, the use of conventional experimental designs and the corresponding data analyses resulted in no consistent statistically significant improvements in yield (*P* = 0.05). Variations in field uniformity, limitations in the number of replications, and crop yield response all contributed to differentiating among treatment responses (Tables 4–7).

Nevertheless, it should be noted that, over all locations and years, the treatment regimen resulting in the highest overall yield consisted of the mid- and late-bloom sequential PIX applications of 0.025 kg ha$^{-1}$ applied 10 to 14 days following first bloom and again 14 days after the first application (Table 8). Using a weighted yield-averaging technique, yields from the 14 independent studies were improved by 60 kg lint ha$^{-1}$ over the 4-year period, from 1993 to 1996. Though these yield improvements were not

**Table 7. Lint yields from four San Joaquin Valley locations in 1996.**

| | Application rate | | | Yield | | | | |
|---|---|---|---|---|---|---|---|---|
| Treatment | Full bloom | 2 wk after first bloom | Cutout | Fresno 96 | Kern 96 | Tulare 95 | Merced 95 | Mean |
| | kg a.i. ha$^{-1}$ | | | kg ha$^{-1}$ | | | | |
| Untreated | -- | -- | -- | 1714 | 1139 | 907 | 1057 | 1204 |
| PIX | 0.025 | 0.025 | -- | 1734 | 1104 | 907 | 1123 | 1217 |
| PIX | 0.037 | 0.025 | -- | 1727 | 1104 | 875 | 1145 | 1213 |
| PIX | 0.037 | 0.037 | -- | 1708 | 1122 | 857 | 1074 | 1190 |
| PIX | 0.037 | 0.049 | -- | 1726 | 1136 | 921 | 1195 | 1245 |
| PIX | 0.037 | 0.037 | 0.025 | 1706 | 1089 | 786 | 1161 | 1186 |
| LSD 0.05 | | | | NS† | NS | NS | NS | |
| CV, % | | | | 3.09 | 4.82 | 9.43 | 10.00 | |

† NS = Nonsignificant ($P$ = 0.05).

**Table 8. Average lint yields after the 0.025 kg ha$^{-1}$ sequential application treatment with PIX over a 3-yr from 14 independent studies. Yield differences are numeric averages of each treatment and not significantly different ($P$ = 0.05).**

| | Application rate | | Yield |
|---|---|---|---|
| Treatment | 14 d after first bloom | 10-14 d following first application | |
| | kg a.i. ha$^{-1}$ | | kg ha$^{-1}$ |
| Untreated | -- | -- | 1390 |
| PIX | 0.025 | 0.025 | 1450 |

statistically significant, we feel that continued evaluations of PIX for Pima cotton are warranted. Further, we have not eliminated the possibility that alternative experimental designs or statistical tools may better distinguish future treatment effects in multiple year, multiple site studies.

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## REFERENCES

Kerby, T. A. 1985. Cotton response to mepiquat chloride. Agron. J. 77:515–518.

Kerby, T. A., and K. D. Hake. 1996. Monitoring cotton's growth. p. 324–334. *In* S. J. Hake et al. (ed.) Cotton production manual. Publ. 3352. Univ. of California Div. of Agriculture and Natural Resources, Oakland, CA.

Kerby, T. A., K. Hake, and M. Keeley. 1986. Cotton fruiting modification with mepiquat chloride. Agron. J. 78:907–912.

Kerby, T. A., B. L. Weir, and M. P. Keeley. 1996. The uses of Pix. p. 294–304. *In* S.J. Hake et al. (ed.) Cotton production manual. Publ. 3352. Univ. of California Div. of Agriculture and Natural Resources, Oakland, CA.

Munier, D.J., T. A. Kerby, and J.C. Matias. 1996. California Cotton Manager Plant Mapping, Version 4.0. Univ. of California Div. of Agriculture and Natural Resources, Oakland, CA.

Munk, D., B. Weir, S. Wright, R. Vargas, and D. Munier. 1997. Pima cotton growth and yield responses to mepiquat chloride (PIX). p. 1401–1403. *In* P. Dugger and D. A. Richter (ed.) Proc. Beltwide Cotton Conf., New Orleans, LA. 6–10 Jan. 1997. Natl. Cotton Council Am., Memphis, TN.

Silvertooth, J.C., J.E. Malcuit, D.R. Howell, and C.R. Farr. 1990. PIX multiple application evaluations in Arizona on Upland and Pima cotton. p. 50–56. *In* Cotton. A College of Agriculture Report. Ser. P-81. Univ. of Arizona, Tucson, AZ.

Silvertooth, J.D., D.R. Howell, C.R. Farr, and J.E. Malcuit. 1989. Evaluation of PIX multiple application treatments on Upland and Pima cotton in Arizona, 1988. p. 104–109. *In* Cotton. A College of Agriculture Report. Ser. P-77. Univ. of Arizona, Tucson, AZ.

Weir, B., and T. Kerby. 1990. Multiple applications of Pix: A three-year summary. p. 649–650. *In* J. M. Brown (ed.) Proc. Beltwide Cotton. Res. Conf., Las Vegas, NV. 9–14 Jan. 1990. Natl. Cotton Council Am., Memphis, TN.