Application of the cultural techniques of cotton leaf-age adjusting-controlling for promotng early maturity

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Summary According to the production index of lint cotton yield over 100kg per *mu* (1/15ha) and the relationship between the climate factors and the distribution of time and space for cotton boll setting in 1985—1990,we established a model of cultural techniques of cotton leaf-age-adjusting-controlling for enhancing early maturity. By utilizing the principle of leaf-age model and the principle of regulating nutrient distribution with DPC(Mepiquate chloride),the plants were treated with DPC in proper time. A new type of population plant patterns was set up. It characterized by high population density,dwarf,high boll weight,bolls near nodes,high energy and low consumption,short distance transport of nutrients,high yield and good quality. We put forward a set of management measures,i. e. adjusting boll setting stage,adjusting and controlling boll setting structure,stably applying N,increasing P,supplementing plants with K,increasing irrigation efficiency,techniques were applied and demonstrated in large areas in high yield and good quality cotton porduction base counties for 5 years in succession. Significant economic and social effects were achieved.

Key words cotton,leaf-age,adjusting-controlling techniques,early maturity

Materials and methods

1 Adjusting boll stage(BS)design. Sowing date:25 March,30 March,5 April,10 April, 15 April,25 April.

2 Boll formation structure design. 3000,4000,5000,6000,7000 plants per *mu*. (1/15 ha).

3 Adjusting-controlling plant pattern design at the stage of 7—8 leaf age. DPC(Mepiquate chloride)was sprayed respectively by 0. 5,1. 0,1. 5 g and Og(control)per *mu*. At the stage of 16—17 leaf-age,DPC were sprayed by 1. 0,1. 5,2. 0,2. 5g and Og(control) per *mu*, 7—8 leaf-age stage 0. 5—1. 0 g per *mu* +16—17 leaf—age stage 1. 5—2. 0 g per *mu*.

4 Irrigation efficiency design. Irrigation was made at full square stage,early flowering stage,full flowering stage and profuse boll stage for the first one. The irrigation norms were respectively 20,30,40,60 cubic metres of water per *mu*.

5 Balancing nutrient design. It consisted of 4 combinations of 3 factors(N,P,K). The fertilizers were appplied by rotary fertilization.

6 Optimum combinations of comprehensive factors design. 5 factors(sowing date,plant density,chemical control,nitrogen and phosphate nutrient,numbers of retainted fruiting branches) and 5 levels design in quadratic orthogonal rotational regression was used.

Results

Adjusting BS to adapt the high peak period of flowering and BS to optimum period of climate factor combination

We analysed the time-space distribution relationship of the local climate ecological factors (1980—1990 Yuncheng Meteorological data) and the cotton flowering and boll-forming stages. The closest correlation existed between the climate factors such as temperature and rainfall etc and the later. At the early developmental stage, the shortage of seedlings was due to low temperature and drought. The seedlings were weak and developed slowly. In the middle stage, high temperature and drought in high summer resulted in less boll-setting and heavy abscission of bolls. At the late stage the early frost and low temperature caused the bolls small and quality poor. The favourable period of flowering and BS were from the last ten days of June to the mid- and-last ten days of July. In this period, the temperature was 20—28 C, rainfall was over 30mm and light supply was abundand. This was the so called the optimum period of 3 factor-combination, which was suitable for flowering and BS. This was the first high peak period of flowering and BS. The experimental data of adjusting boll stage indicated that all those plants grown before April 10 could come into bloom before July 1. The percentage of flowering before July 25 accounted for 70. 5%—78. 7% of the total flowers, whereas those planted after April 10, even April 25 were delayed to bloom in period from July 5 to July 15. The percentage of flowering and BS before April 25 were delayed to bloom in period from July 5 to July 15. The percentage of flowering and BS before July 25 only accounted for 50. 2%—65. 5% and 45. 3%—51. 1%. In this high peak period, the percentages of flowering and BS were excessively high. The BS percentage for other treatments was 85. 2%—98. 8%. The period from July 25 to August 10 was the high peak period of abscission. The numbers of flowering and BS decreased to the lowest point. In this period, the numbers of flowering and BS (planted before April 10) accounted for 10. 1%—15. 8% and 15. 5%—20. 2% respectively. Those of plants grown after April 10 acounted for 14. 2%—21. 3%, 18. 6%—21. 5%. The mid- and-last ten days of August was the second high peak period for flowering and BS. It was the optimum period of climate ecological factor combination, but the duration was short. The numbers of flowering and BS (planted before April 10) accounted for 11. 2%—13. 7%, 5. 9%—11. 4% respectively. Those planted after April 10 accounted for 30. 3%—38. 5% and 29. 2%—34. 3%.

It was clear that the first peak value of flowering and boll setting (FBS) of cotton planted before April 10 was higher. The second peak value was lower. Both peak values of cotton planted after April 10 were almost similar or the second value was a little higher. In the same time, the data indicated that they were different in boll size, boll weight and fiber quality of bolls formed in different periods of FBS. It may be seen that the boll size, weight, fiber quality were increased or decreased with the date (earlier or later) of FBS. The positive correlation existed between the boll size (big or small) and FBS (early or late) of every parts of plants. The correlation coefficient was $r=0.7062^{**}$. However the positive correlation existed between the boll size (big or small) and boll weight, $r=0.803^{**}$, which indicated that the bolls formed in the first high peak period increased fast and the ratio of big boll was high. According to the statistics, daily increasing of weight of boll formed before and in full summer was 2. 3—2. 8 times as fast as those planted late. The boll weight was increased by 0. 49—1. 11g. For example, 5—6g boll formed from late June to mid July accounted for 20. 2%, 6—7g boll, 11. 7%, 7—8g boll, 2%, whereas those planted late only accounted for 11. 3%, 4. 3% and 0. 8%, respectively. The positive correlation existed between fiber quality and FBS date (early or late), $r=0.9764^{**}$. For example, from late June to July 10, the single fiber strength of the bolls set in the first node of the 1st — 3rd fruiting branches, was 4. 49g; its fineness was 5827. 8m/g and breaking length was 27. 37km. From July 11 to 20, single fiber strength of bolls set in the 1st—3rd nodes of the 1st—7th fruiting branches was 4. 38g; its fineness was 5669. 8m/g and breaking length was 26. 38km. During July 21—30, single fiber strength of bolls set in the 1st—4th nodes of the 6th—10th fruiting branches was 4. 22g; its fineness was 5416. 8m/g and breaking length was

25.47km. During August 1—10, the single fiber strength of bolls set in the 3rd—4th nodes of the 8th — 12th fruiting branches was 4.17g; its fineness was 4976m/g and breaking length was 25.31km. It was clear that its fiber quality was gradually decreased with the dates of FBS delaying. Therefore, adjusting BS stage by adjusting sowing date and early sowing in proper time was an economical effective measures for achieving early development and maturity, high yield and good quality. The traditional idea so called "early sowing, but not early development" was reformed. It is proved in practice that sowing in late march-early April could not only achieve an increase in yield by 15%—20%, but also accomplish the growing process in full seedlings in April, squares in May, flowering in June, and boll opening in August. Therefore adjusting sowing time (early sowing in proper time) was one of the most important cultural measures.

Adjusting-controlling the BS structure, increasing big bolls and good quality bolls near the main stems

According to the samples collected from different population density and the analysis data from 900 series of Chinese Cotton Research Institute it was shown that the fiber quality index i.e. boll weight, 2.5% span, uniformity, Micronaire value, specific strength and elongation rate of bolls in the 4th nodes per fruiting branches from the 1st—10st fruiting branches, varied regularly with the time and space of FBS. The boll weight, lint and other quality index in the 1st node were the highest, followed by those of the second node which were almost similar to the first node. Those in the 3rd node and other far nodes significantly decreased with the extension of node. Those quality indices were acompanied by a regular progressive decrease. For example, boll weight was 5.4g, lint 0.2%, 2.5% span 29.6, uniformity 47.9, specific strength 22.5, elongation rate 7.2, Micronaire value 4.9 in the 1st node of the 1st fruiting branches. In the 2nd node, they were 5.1, 41.0, 28.4, 47.9, 23.8, 7.7, 4.7. In the 3rd node, 4.8, 39.7, 28.3, 45.2, 22.2, 7.1, 3.5 respectively, and in the 4th node, 4.5, 39.1, 26.8, 45.6, 22, 1, 6.4, 3.3. The variation pattern of each fruiting branch and each node mentioned above was the same. Therefore, the numbers of bolls in the 1st—2nd nodes must be increased in order to achieve early maturity, good quality and big bolls.

Only increasing the population density and total nodes of the 1st—2nd nodes in unit area could increase the numbers of good quality bolls of the 1st—2nd nodes. The experimental result indicated that in the condition of population density of 3000—4000 plants/*mu*, there were 13 fruiting branches/plant and 78—104 thousands nodes of the 1st—2nd nodes of unit area; in condition of 5000—6000 plants/*mu*, there were 10 fruiting branches/plant and 100—120 thousands nodes of the 1st—2nd nodes of unit area.

With the increase of the population density and the 1st—2nd nodes, combined with corresponding measures of chemical control and adjusting-controlling water-fertillzer, the BS rate of the 1st—2nd nodes was increased and early maturity of unit area and good quality bolls were achieved. The experimental data indicated that in the condition of 3000—4000 plants/*mu*, there were 18.1—16.4 bolls/plant, 54.3—65.6 thousand bolls/*mu*, the bolls of the 1st—2nd nodes accounting for 65.4—70.2%, and 35512.2—46051.2 bolls of the 1st—2nd nodes/*mu*; in the condition of 5000—6000plants/*mu*, there were 12—10.8 bolls/plant, 60—64.8 thousand bolls/*mu*, the BS rate of the 1st—2nd nodes accounting for 80.5—90.1% and 48300—58384.8 bolls of the 1st—2nd nodes/*mu*.

With the increase of the bolls in the 1st—2nd nodes and variation of boll position, the average boll weight was 4.46g/plant and the boll weight of the 1st—2nd nodes was 4.53g. On the basis of calculating the bolls of the 1st—2nd nodes, the density of 3000—4000 plants/*mu* could produce lint cotton 64.05—83.1 kg/*mu* which accounted for 67.8—72.8%; and 5000—6000 plants/*mu*, lint cotton yield 87.52—105.79kg/*mu*, accounted for 81.76—91.5%. Therefore, increasing the population density combined with the corresponding chemical control and water-fertilizer adjusting-controlling was a key measure for controlling cross and longitudinal growth of cotton plants, reducing plant height, shortening fruiting branches and adjusting-controlling BS position, and increasing good quality bolls.

Coördinating the relationship of growth and development of plant, establishing good population plant patterns

The relationship between vegetative growth and reproductive growth was coordinated by chemical control. The establishment of ideal population plant patterns was another indispensable key measure in the condition of high density.

The experimental data indicated that the lint cotton yield of the whole plants evenly treated with chemicals twice at 7—8 leaf-age stage and 16—17 leaf-age stage was increased by 9.1%—13.4% as compared with that of plants treated with chemicals once. The increase in yield for 0.5—1.0g/ *mu* and 1.5—2.0g/ *mu* was larger(by 13.5—19.7%). The excessive or less chemicals couldn't increase the yield, and even decreased it. Its plant pattern was either tall or dwarf and overgrown. If the plants were treated with chemicals twice, we could get a type with dwarf plant pattern, short branches, small blade, big bolls, high yield and good quality, which the plant height was less 1m(90—95cm); internode length was less 6cm(5.4—6.0cm); fruiting branch length was less 20cm(15.3—19.8cm); leaf width was 15—20cm(15.8—18.4cm); BS rate was about 90%(87.5—93.4%) in the 1st — 2nd nodes; leaf area index was 3.75—4.0; biomass was 750kg or so (745.3—791.2kg); lint cotton yield was over 100kg per *mu* (105.4—115.5kg) and economical coefficient was 0.37 or so(0.357—0.385).

The statistical data indicated that this type of plant pattern with dwarf plant, short branches, small blade and big boll increased the efficiency of light energy conversion by 0.072% as compared with that of plants without chemical control, because there existed no cross between branches and the leaves were not overlapped. In the mean while, the shortened distance of nutrient transport made water saved by 46.6%.

The study on the whole plant controlled with chemical twice replaced the lopsided idea that chemical control was only used for preventing plant from excessive vegetative growth. It also altered the traditional idea that "seedlings can not be controlled with chemicals" and "during full square-early flowering stage, the plants can not be controlled with chemicals until the growth speed reaches over 2.5cm daily". Chemical control is a kind of cultural technique of promoting early maturity of cotton. It can coordinate the relationship between vegetative growth and reproductive growth, the relationship between the aerial parts of plant and the under-ground portion of individual plant and population plants, environment and cotton plant growth. The correct chemical control could play a part in controlling the aerial parts, enhancing underground portion of plant.

Coordinating the proportion of nutrients, stably applying N, increasing P application and supplementing plants with K, keeping balance of fertilizer application

At present, excessive N application, less P, and even no K application were done in high yield cotton fields. The proportion of N, P, K was out of balance and the amount of additional application of fertillzers at the early stage was more than those at the late stage, resulting in slow development of plants. In order to solve those problems, the ratory design with 3 factors(N, P, K) and 4 combinations was used. The response model between lint cotton yield and N, P, K was established as follows:

$$Y=123.75+3.20X_1+1.96X_2+1.54X_3+2.48X_1X_2-3.17X_1^2-3.38X_2^2-1.86X_3^2$$

66 sets of N, P, K combination were obtained. Each combination could get lint cotton yield over 110kg/ *mu*. The N, P, K combination for maximum yield (125kg lint cotton/ *mu*) was pure N 9.5—10.34kg, P_2O_5 5.52—6.75kg, K_2O 5.25—5.70kg (N:P:K= 1:0.58—0.65:0.55).

$$\hat{Y}=125.35\pm8.42\text{kg} \qquad (\alpha=0.05)$$

The result of further analyses for N, P, K effect indicated that the soil type in the North was carbonate soil. Both N and P play an important role in yield forming. The increasing yield effect of N was more than that of P and K. K application indeed had increasing yield effect. For example, the yield of the fields applied K_2O 5kg/ *mu* was increased by 17.3% as compared with that of fields without K_2O application and increased by 8.9% as compared with that of the fields applied P_2O_5 4.5kg/ *mu*, but decreased by 5.35% as compared with that of the fields with pure N 7.5kg/ *mu*. K application had a significant role in increasing boll weight and lint.

The experimental result showed that the proportion of N:P:K=1:0.6:0.5 was suitable for getting lint cotton yield over 100kg/ *mu*. Thus the unsuitable proportion of N:P (1:0.3—0.4) and neglecting K application were altered. At the same time, the fertilizer application technique of early heavy fertilizer application and late light fertilizer application was turned into early light fertilizer application and late heavy fertilizer application. Under the condition of pure N 10kg/ *mu*, one third was used as seed manure and two thirds as top application at the stage of flowering and BS. The information feed back from large areas proved that this kind of keeping balance of fertilizer application could increase the average lint cotton yield by 4.8—6.4kg/ *mu* (7.89—15.0%).

Adjusting the irrigation date, controlling the irrigation norm, carrying out water-saving irrigation, increasing the irrigation efficiency

It rains less and water resources is not rich in this region. In respect of irrigation technique, the irrigation time was too early and excessive irrigation resulted in waste of water. The irrigation efficiency was very low. About 4 cubic meters of water were used to produce 1kg of lint cotton (0.25—0.3kg lint cotton/m^3 water) for an average year. Therefore, adjusting the irrigation time and controlling the amount of irrigation were the measures for increasing irrigation efficiency and enhancing early maturity of cotton.

The experimental data showed that on the basis of irrigation 80 cubic meters of water per *mu* prior to sowing in the growing period lint cotton 100kg/ *mu* could be obtained by irrigating 1—2 times (80 cubic meters of water) at the full flowering stage. The irrigation efficiency could be increased by 0.5kg lint cotton/ *mu*. For example, at the early stage and the mid-stage of growing season in 1986, it was drought. The rainfall of the whole season was equivalent to 1/2 of an average years. At the full flowering stage, the plants were watered 2 times in succession (the whole amount of irrigation: 70 cubic meters of water). Lint cotton 101.1kg/ *mu* could be obtained. The irrigation efficiency was 0.67kg lint cotton/ *mu*. The lint cotton yield was 5.6kg/ *mu* less than that of the fields irrigated 3 times (130cubic metres of water/ *mu*) in succession at the early flowering stage and 15.9kg less than that of fields watered 4 times (190 cubic metres of water/ *mu*) in succession at the full square stage, but the irrigation efficiency was respectively increased by 0.16kg and 0.24kg. In 1987, it rained more and the rainfall distribution was even at the early flowering stage and full flowering stage. When 30 cubic meters of water/ *mu* was only watered 1 time at the full flowering stage, the lint cotton yield reached 111. 6kg/ *mu* and the irrigation efficiency was 1. 0. The lint cotton yield was increased by 7. 0kg/ *mu* as compared with that of fields watered 3 times(130 cubic metres of water/ *mu*)in succession. It was increased by 7. 5kg/ *mu* as compared with that of fields watered 2 times(70 cubic metres of water/ *mu*) at the full square stage. The irrigation efficiency increased 0. 502kg and 0. 306kg, respectively. In 1988, it was drought at the early season and it rained much at the mid-late season. At the full flowering stage, the lint cotton yield reached 95. 8kg/ *mu* and the irrigation efficiency was 0. 64kg in watering 2 times(70 cubic meters of water/ *mu*). The lint cotton yield was increased by 2. 6kg/ *mu* as compared with that of fields watered 3 times(120 cubic meters of water/ *mu*)in succession at the early flowering stage. The irrigation efficiency was increased by 0. 17kg. In 1989, it was drought in the whole season and high temperature and drought in full summer lasted for 40 days. At the full flowering stage, lint cotton yield was 123. 3kg/ *mu* in watering 2 times(80 cubic meters of water/ *mu*)and the irrigation efficiency was 0. 71kg. Though the lint cotton yield was 7. 1kg less than that of fields watered 3 times(120 cubic meters of water/ *mu*)in succession at the early flowering stage, its irrigation efficiency increased by 0. 12kg.

The results of water-saving irrigation experiment showed that on the basis of upward irrigation, the irrigation times and the amount of irrigation were reduced and the irrigation efficency was 0. 5—1. 0kg in the whole growing season by watering 1—2 times (30—40cubic metres of water per *mu* each time)at the full flowering stage. This altered the conventional irrigation practice (i. e. at the stage of early and full flowering, watering 3—4 times in succession at intervals of 7—10days), and also corrected the irrational irrigation practice(i. e. irrigating before early flowering stage, irrigation 60—80 cubic meters of water/ *mu*). On the basis of lint cotton yield 100kg/ *mu* , we reduced the investment and increased the income by means of adjusting the irrigation time, controlling the irrigation norm and saving water 40—120 cubic meters of water/ *mu* .

Using comprehensive study for standardizing and quantifying the key measures

Using many years experimental data and various single research results from every scientific research centres, applying the system engineering principle of the optimum simulated combination and adapting regression design, we studied the relationship between the key techniques of promoting early maturity and yield formation, established a model of yield function and ascertained the optimun technique combination of different ecology, production, fertility and yield levels and the interaction effect of the measures.

The experimental result indicated that the yield mathematic model of the experimental plan in 1985—1989 was well consistent with the tested values and the function relationships existed between the measures and the yield. The optimum combinations for 3 types of cotton fields were as follows: in high fertility condition the combination consisited of lint cotton yield 120kg/ *mu* , population density 4012—4960 plants/ *mu* , sowing date 4—10, April, N application 8. 2—11. 4kg/ *mu*, P fertilizer 40—63. 6kg/ *mu* , DPC 3. 2—4. 34g/ *mu*, 14. 2 fruiting branches/plant. In moderate fertility condition it consisted of lint cotton yield 100kg/ *mu* , population density 4611—4891 plants/ *mu* , sowing date 5—10, April, N application 9. 2—11. 2kg/ *mu* , P fertilizer 40—59. 9 kg/ *mu* , DPC 3. 2—3. 65 g/ *mu* , 12. 8—13. 5 fruiting branches/plant. In low fertility condition, lint cotton yield 80kg/ *mu* , population density 4881—5490 plants/ *mu* , sowing date 5—8, April, N application 9. 9—12 kg/ *mu* , P fertilizer 40—63. 3kg/ *mu* , DPC 2. 67—3. 16g/ *mu* , 13—14 fruiting branches/ plant.

Every key measure affected the yield formation to a degree and the functions were different. The function effect of population density, chemical control and P fertilizer application rate in the high fertility condition was maximum. The function effect of population density, N application rate and P fertilizer in the low water-fertility condition was maximum. The interaction existed among the key measures. The interaction between the population density and the chemical control was positive. The interaction between the population density and the numbers of fruiting branches was negative. Positive interaction existed between N fertilizer and chemical control, and negative interaction existed between N fertilizer and P fertilizer. It also indicated that the amount of chemical used increased with the increase of population density as key in order to prevent plants form excessive growth, late development and maturity. When applying N fertilizer, we payed attention to increasing P fertilizer application. The interaction between N and P showed that P effect was higher than N effect in the high and the moderate fertility cotton fields. Therefore, in the high fertility cotton fields, only increasing P fertilizer application could give full play of N fertilizer. The proportion of N and P should be 1:0. 82—0. 85. In the low water fertility cotton fields, N effect was larger than P effect and the optimum N:P proportion was 1:0. 7.

The optimum combination measures of 3 types of cotton fields were demonstrated in 26. 5 thousand *mu* fields. The average lint cotton yield increased by 1. 2 kg/ *mu* (12. 3%)in the high water-fertility cotton fields, by 12. 1 kg/ *mu* (14. 1%)in the moderate water-fertility cotton fields and by 11. 7kg/ *mu* (15. 3%) in the low water-fertility cotton fields.

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References

Fan Zhijie et al. (1990) Study on cotton-yield simulation model and its application under combination of agronomic measures with film-mulching for good quality and high yield. *Scientia Agricultura Sinica*, 23 (2):57—66(in Chinese)

He Zhongpei et al. (1984) Directional and fixed quantity induction of DPC effect and its application in cotton high yield cultivation. *Journal of Beijing Agricultural University*, 10(1)(in Chinese)

Jia Lailing et al. (1986) A good method of increasing cotton fiber quality——promoting early maturity cultivation of short, dwarf, donse. In: Research Paper Collection of the Sixth Scientific Conference, China Cotton Association(in Chinese)

Jiang Guozhu et al. (1987) The optimum fruiting pattern for high yield and high quality of cotton and the conditioning technique. *Chinese Journal of Cotton*, 3(5):25—27(in Chinese)

Li Peiming et al. (1986) Study on the efffect of DPC chemical controlling on cotton canopy structure and ecological effect in cotton fields. Transactions of Cotton(Trial Pub.), No 2, 13—21(in Chinese)