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EFFECT OF POTASSIUM FERTILIZATION ON POTENTIAL FRUITING POSITIONS IN FIELD GROWN COTTON

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Abstract

A field experiment was conducted to assess the effectiveness of fruiting positions along sympodia under varying levels and sources of potassium fertilizer on field grown cotton under an arid environment. The treatments consisted of four rates of potassium (0, 62.5, 125.0, 250.0 kg K ha^{-1}) and two sources of potassium (K_2SO_4 and KCl). Cotton cultivar CIM-1100 (*Gossypium hirsutum* L.) was used as test crop. Plant mapping data showed that total number of fruiting positions, number of intact fruit on sympodia / monopodial and percent of bolls per position on sympodia differed greatly due to different doses of potassium fertilizer. The percentage of fruit retention was markedly improved due to increasing doses of K-fertilizer compared to K-unfertilized treatment. The percent survival of harvestable bolls for the five first positions along sympodia at the end of season was 30, 25, 18, 13 and 8, respectively. Potassium fertilization stimulated cotton crop in lengthening sympodial branches and retaining more fruit on the three first positions and also at the bottom of plant during early reproductive phase. The fruiting pattern was 2 to 3 and 6 to 7 days vertical and horizontal fruiting interval, respectively.

Introduction

The yield of cotton crop is dependent upon the environment in which it grows and the management practices that are imposed on the cropping system. Current estimates are that about 70% of the variation in yield from year to year is dependent upon the environment and only 30% of the variation is subjected to management. The major environmental constraints include the weather, the nutrient status and the insect pest situation. Management practices must be designed and implemented to minimize the risk of adverse environmental conditions drastically reducing yield during the season (Krieg, 1997). The eventual yield level depends greatly on the ability of the crop to overcome the situation by resistance or tolerance. A crop well supplied with nutrients in a balanced proportion has a better chance to survive and to produce a fair yield (Johnson & Addicott, 1967).

Cultivated cotton is a perennial plant with an indeterminate growth habit that has adapted to annual crop culture. It grows in an orderly manner with a monopodial vegetative mainstem and lateral monopodial and sympodial fruiting branches. Plants must grow vegetatively to produce fruiting sites until subjected to internal or external stress i.e., temperature, moisture, nutrients, boll load and interactions of these factors can cause cessation of growth (Kohel & Benedict, 1987). Earliness of crop maturity has been given a great deal of attention, as it is greatly influenced by management practices rather than variety selected which ultimately affects profitability and risk (Kerby *et al.*, 1995).

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Yield improvement in modern cotton (*Gossypium hirsutum* L.) cultivars has become stagnant in the recent years, resulting in a plateau that cotton yields have not been able to breakthrough. A potential strategy for reducing production costs, is by shortening the growing season, which will entail growing cotton in high potential yield levels (Regmi & Roberson, 1977).

The advantages of earliness include defoliating and harvesting under more favourable conditions, improved fibre quality and decreased yield losses (Kerby *et al.,* 1995). Many factors may affect earliness i.e., plant date (not genetic), node number of first fruiting branch, the rate at which new fruiting node develops, early boll retention, the number of nodes required to set all harvestable boll and the boll period. These genetic variables can be quantified within season and constructing plant maps at maturity (Meredith & Wells, 1989).

The distribution of the bolls on the plant varies due to abscission from physiological and environmental causes. Plant diagrams are used to “map” the positions of bolls and are useful management tools to follow fruit development and assess the success of production inputs (Oosterhuis, 1990). The fruiting positions along a fruiting branch varies i.e., the first, second and third, sympodial positions contribute about 60%, 30% and 10% of the total seed cotton yield respectively. Furthermore, the lint quality tends to decrease away from the main stem (Jenkins *et al.,* 1990).

The mapping of fruit retention characteristics of cotton has been practiced for many years in various ways according to the particular aspects, which are of interest at the time. Nearly all of them wanted, to know, when and how the crop was produced during the season and as well as the total yield of seed cotton (Farbrother, 1981). Tharp (1960) measured the orderly time schedule of cotton plant by the sequence of flower opening. An individual plant was mapped daily. Data showed *inter alia* that an average successive flowers on the same branch opened at intervals of seven days (the horizontal interval); the first flower on successive branches opened at three-day intervals (the vertical interval) and the second, third and late flowers were similarly separated. The vertical flowering interval corresponds to the development of the nodes up the main stem. Munro & Farbrother (1969) have reviewed a comprehensive study on practical aspect of growth analysis using composite plant diagrams in cotton. Other researchers adopted the triangular projection of the upward and outward development of the flowering pattern and divided into zones of contemporary flowering. Each zone contained the number of fruiting positions expected to develop in a two week period. In the recent years, its use has been increasing in the United States of America (Constable, 1991). Consequently, information on the affects of various inputs is needed to improve recommendations made by plant mapping interpretation (Zelinski & Grimes, 1995). The influence of variety (Heitholt, 1993), insects (Holman *et al*., 1994), fertilizers (Zelinski & Grimes, 1995) on cotton growth, development and fruit retention has been quantified through plant mapping technique for refinement of management practices. Stinger *et al*., (1990) reported that nitrogen fertilization increased fruit retention by sympodial branch and position.

Therefore, studies were undertaken to map the production and survival of fruit as influenced by potassium fertilization on field grown cotton.

Table 1. Physical and chemical characteristics of the experimental site before the imposition of treatments.

Characteristics		Depth (cm)			
		0-30	30-60	60-90	90-120
a)	Organic matter (%)	0.67	0.61	0.38	0.21
b)	$CaCO_3$ (%)	4.8	4.8	4.9	2.5
c)	pH_s	8.3	8.4	8.4	8.4
d)	EC_e (dS m^{-1})	2.5	3.9	3.1	4.1
e)	CO_3^{2-} (meq L^{-1})	Nil	Nil	Nil	Nil
f)	HCO_3^{2-} (meq L^{-1})	2.38	3.64	2.56	2.16
g)	Cl^-(meq L^{-1})	4.9	5.3	5.3	5.4
h)	SO_4^{2-} (meq L^{-1})	15.5	20.4	21.9	24.3
i)	$Ca^{2+} + Mg^{2+}$(cmol$^+$ kg^{-1})	0.20	0.24	0.40	0.17
j)	Na^+ (cmol$^+$ kg^{-1})	2.30	3.66	2.60	3.98
	Cation exchange capacity (cmol$^+$ kg^{-1})	5.20	4.80	4.40	4.30
	NO_3-N (mg kg^{-1})	6.8	5.3	4.1	3.8
	$NaHCO_3$-P (mg kg^{-1})	14.3	7.2	2.8	2.2
	NH_4OAc-K (cmol$^+$ kg^{-1})	0.38	0.24	0.23	0.22
	Sand (%)	17	15	14	14
Soil separates	Silt (%)	58	61	61	64
	Clay (%)	25	24	25	22
Textural class		Silt loam	Silt loam	Silt loam	Silt loam

The parameters from a to j were determined in the soil solution extract.

Materials and Methods

The experiment was conducted at Central Cotton Research Institute, Multan (30° 12' N, 71° 28' E, alt. 123m) a central location for cotton cultivation in Pakistan. Soil samples were collected before imposition of fertilizer treatments at planting time. Soil analysis was carried out as per methods described by Ryan *et al*., (2001). Soil analytical data are given in Table 1. The soil is silt loam, moderately calcareous, medium in exchangeable and developed in an arid subtropical continental climate. The soils belong to Miani soil series and classified as Calcaric Cambisols and fine silty, mixed Hyperthermic Fluventic Haplocambids according to FAO (Anon., 1990) and USDA classification (Anon., 1998) systems respectively.

Cotton cultivar CIM-1100 (*Gossypium hirsutum* L.) was planted on May 27, 2000 at a spacing of 75 cm between rows and 30 cm between plants in the rows. The treatments consisted of (a) four potassium doses (0, 62.5, 125.0, 250.0 kg K ha^{-1}) and (b) two potassium sources [sulphate of potash (K_2SO_4) and muriate of potash (KCl)]. The design of the experiment was split plot having four replications. Crop also received 50 kg P_2O_5 ha^{-1} as triple super-phosphate at planting and 150 kg N ha^{-1} as urea in three split doses i.e., planting, flowering and peak flowering. The whole quantity of potassium and phosphorus was applied at the time of seedbed preparation and incorporated in the upper plough layer. Chemical spray of Stomp-330E @ 2.5 litre per hectare as pre-emergence herbicide was applied to control weeds. Mechanical weed control was also carried out as needed to keep crop free of weed infestation. Relative low action thresholds were used for insect-pest management in order to minimize damage to growing points and fruit during the season. Crop received normal irrigation and strict crop husbandry practices of the area throughout the season.

Five plants per treatment free of mechanical damage or obvious defects and with plants on either side within the row were individually selected. All flowers on these plants were tagged with dated tags on the day of anthesis for recording data on horizontal and vertical flowering interval. The data on single plant basis were recorded by mapping four plants per treatment at the end of season. The selected plants did not have terminal damage at any point during the season and spacing between adjacent plants was typical for the field. The symbols were used to distinguish different stages of development (Munro & Farbrother, 1969): full diameter boll (D), open /husk after splitting of boll (H) and shed buds or bolls (x). Data on number and outcome of all fruiting positions produced by the plant in each contemporary zone were arranged in a frequency table according to Munro & Farbrother (1969). Data were analyzed by applying split plot design (dummy plot technique) according to method of Gomez & Gomez (1984). The least significant differences test at 0.05 and 0.01 probability was applied to test the significance of the treatment means.

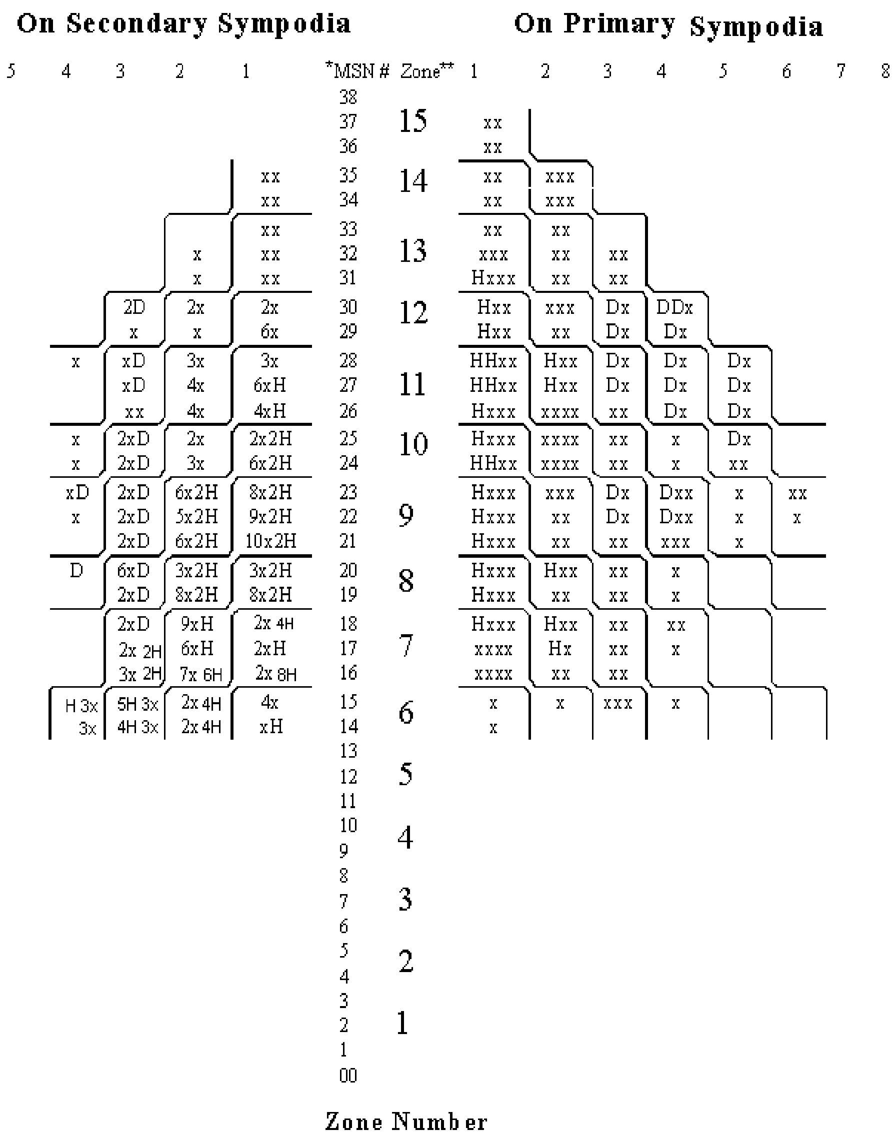
Results and Discussion

The ability of cotton to retain fruiting positions is critical for economic yields. One measure of this property is percent retention in five first positions fruiting forms. The effects of potassium fertilizer on this property are illustrated in Fig. 1 to 7.

It was apparent from plant mapping and data collection that all fruiting sites on the plant differed due to potassium fertilization. Differences were apparent in total number of fruiting positions, number of intact fruit on monopodia and sympodia. The fruiting pattern for cv. CIM-1100 was 2-3 and 6-7 days vertical and horizontal fruiting intervals, respectively.

Analysis of production of fruit retention for five first positions revealed wide differences due to potassium fertilization. The increasing doses of potassium fertilizer resulted in increased percentage of fruit retention compared K-unfertilized treatment. The survival rate of fruiting positions at bottom 15 stem nodes was small than the middle of plant. Crop under K-unfertilized treatment showed lower survival rate of fruiting positions along sympodia than under potassium fertilized crop. The percentage of boll retention on three first positions was 36, 21 and 19 under K-unfertilized treatment compared to 42, 18 and 17 under 250 kg K ha^{-1} in the form of SOP treatment, respectively. At position one where most of the yield is produced, treatments differed greatly at nodes 14 through 25. This study suggests that K-fertilization can effect retention of young squares to develop into harvestable bolls.

Mapping the fruit survival showed that from nodes 14 through 25, there were increasing number of bolls on each sympodial branch and after node 25, decreasing number of bolls on each sympodial branch were observed. The peak values for position one were node 16 to 23 and node 14 to 20 for position two (Table 2). Similarly Jenkins *et al.*, (1990) study showed that node 9 to 10 was the peak for position one and nodes 8 to 10 for position two. They reported that about 90% of the total yield was produced at fruiting positions one, two and three on the sympodial branches. In our study, it was found that most of harvestable bolls were retained from nodes in the middle of plant (generally 16 to 25). Moreover, percentage boll retention varied from 76 to 80 at three first positions under different K-fertilizer treatments.

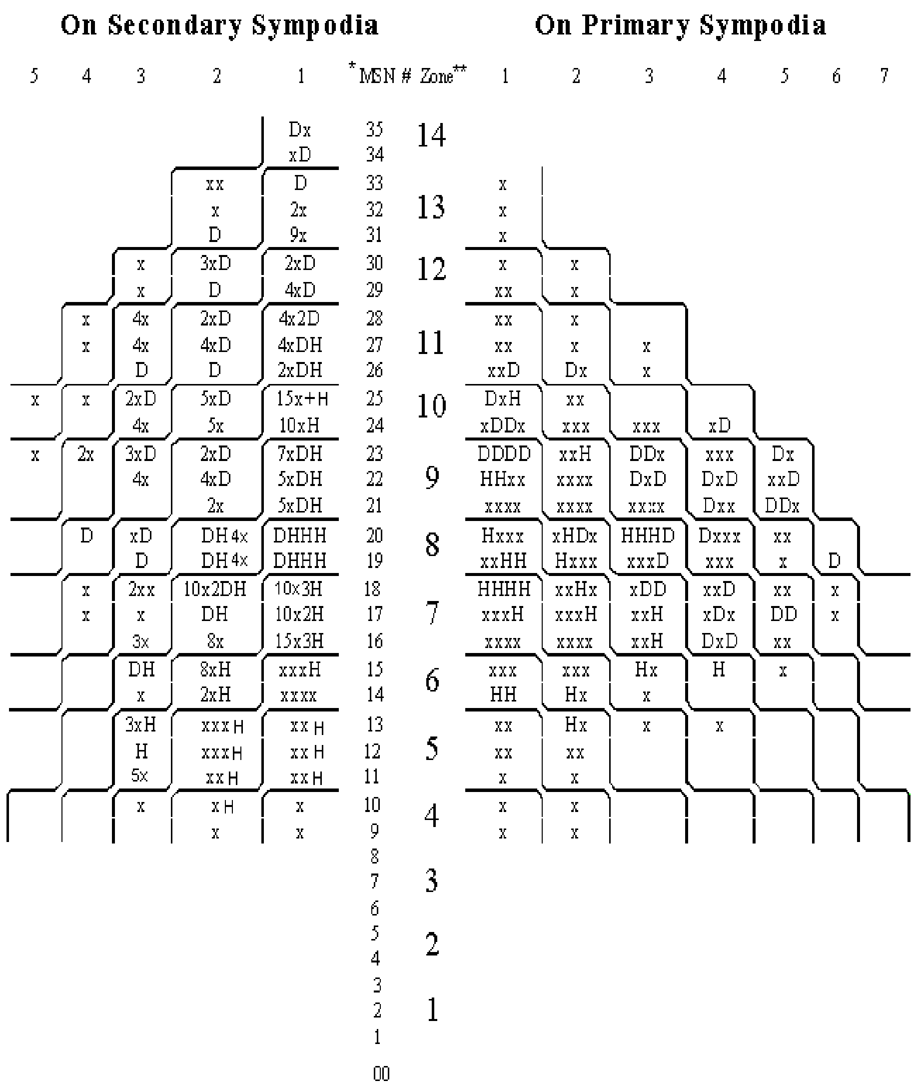


On Secondary Sympodia																				*On Primary Sympodia*	
Σ	**14**	**13**	**12**	**11**	**10**	**9**	**8**	**7**	**6**	**Sym**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**Σ**
209	8	14	25	24	33	51	39	10	5	x	2	12	14	20	19	21	23	22	21	19	173
14	2	2	3	4	2	1				D						2	2	2	6	6	18
70				2	10	15	21	21	1	H		1	4	4	2	5	4	1			21
293	10	16	28	30	45	67	60	31	6	Σ	2	13	18	24	21	28	29	25	27	25	212
											6	31	60	67	45	30	28	16	10		293
										Σ	8	44	78	91	66	58	57	41	37	25	505

* Main stem node number

**Bold numerals denote zone number

Fig. 1. Fruit production efficiency as affected by K-unfertilized treatment in cv. CIM-1100.

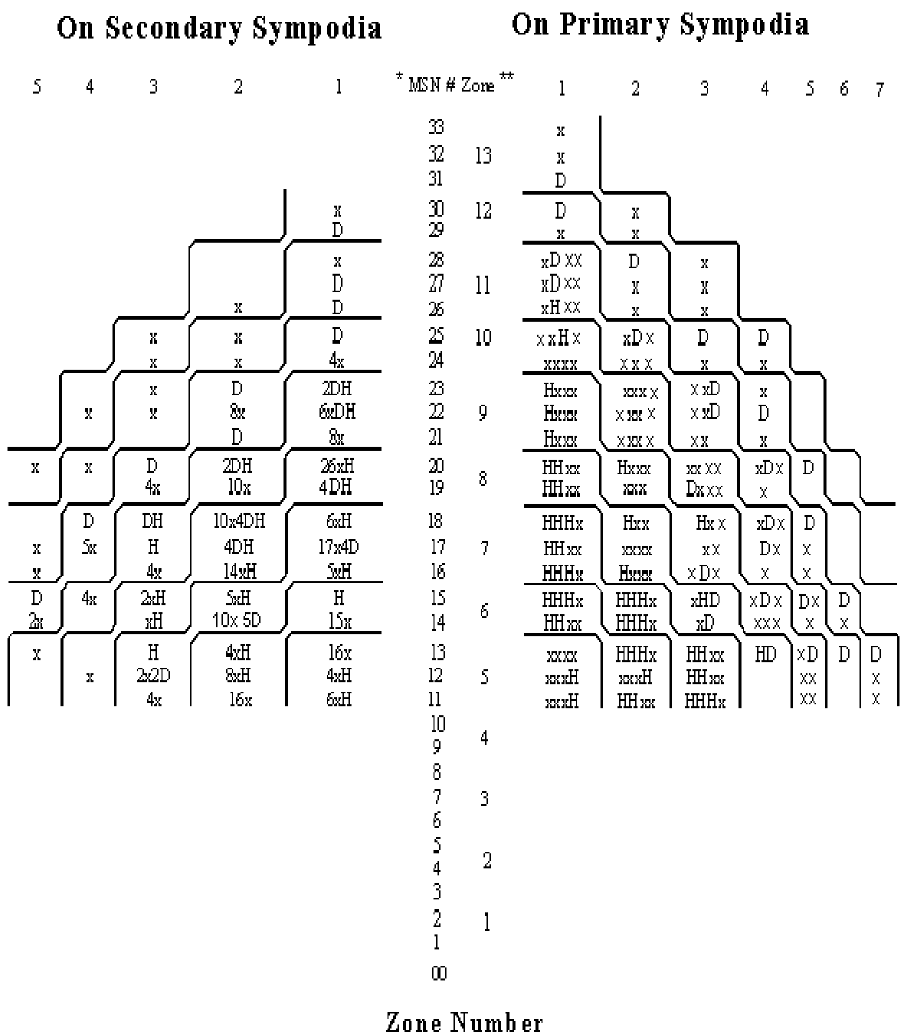


On Secondary Sympodia													On Primary Sympodia											
Σ	**14**	**13**	**12**	**11**	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**Sym**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**Σ**
244	10	22	19	27	36	32	19	53	16	8	2	**x**	2	7	7	12	18	16	22	27	20	12		143
32	3	2	6	7	4	5	5					**D**						7	9	8	4	6		34
38				2	2	4	9	12	4	4		**H**				3	5	6	7	5				26
314	13	24	25	36	42	42	33	65	20	12	2	**Σ**	2	7	10	17	24	30	36	35	24	18		203
													2	12	20	65	33	42	42	36	25	24	13	314
												Σ	4	19	30	82	57	72	78	71	49	42	13	517

* Main stem node number

**Bold numerals denote zone number

Fig. 2. Fruit production efficiency as affected by application of 62.5 kg k ha^{-1} as KCl in cv. CIM-1100



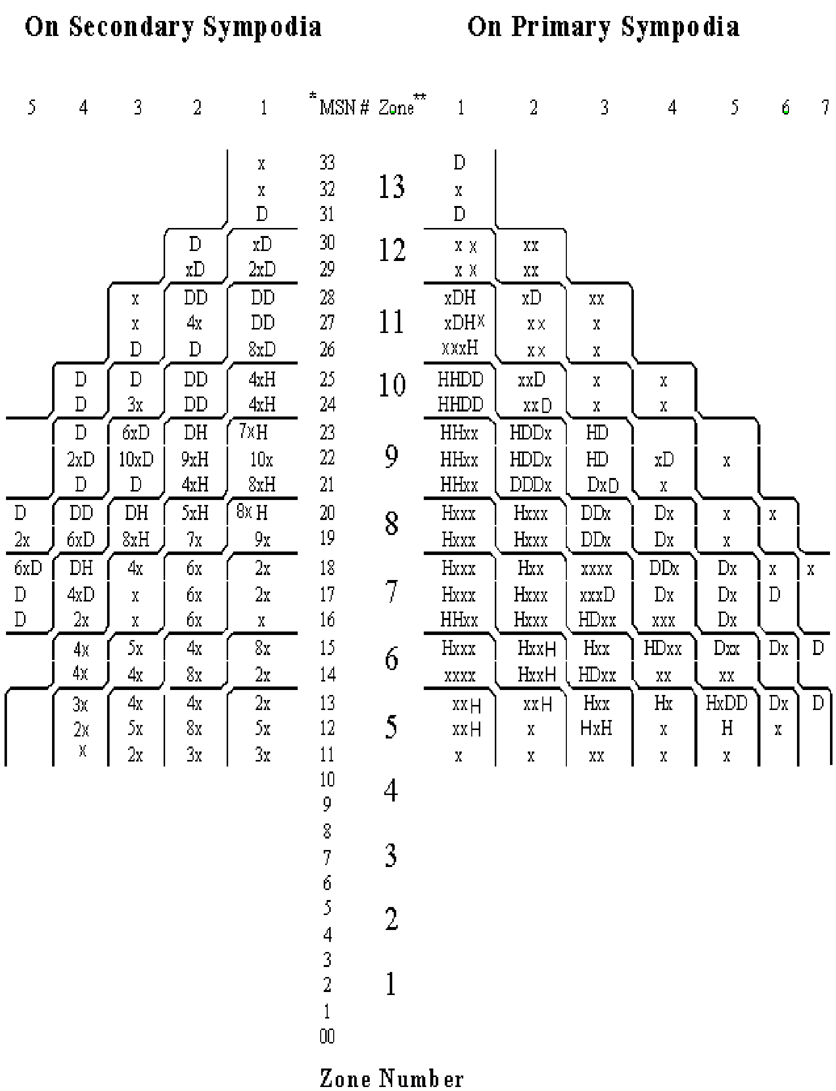
On Secondary Sympodia / On Primary Sympodia

Σ	12	11	10	9	8	7	6	5	Sym	5	6	7	8	9	10	11	12	13	Σ
242	6	8	23	33	54	49	43	26	x	10	9	11	15	31	34	28	6	8	152
38	1	2	6	6	12	11			D				3	3	5	9	5	2	27
21				5	7	4	3	2	H	2	11	21	8	5	1	1			49
301	7	10	29	44	73	64	46	28	Σ	12	20	32	26	39	40	38	11	10	228
										28	46	64	73	44	29	10	7		301
									Σ	40	66	96	99	83	69	48	18	10	529

* Main stem node number

**Bold numerals denote zone number

Fig. 3. Fruit production efficiency as affected by application of 62.5 kg K ha^{-1} as K_2SO_4 in cv. CIM-1100.

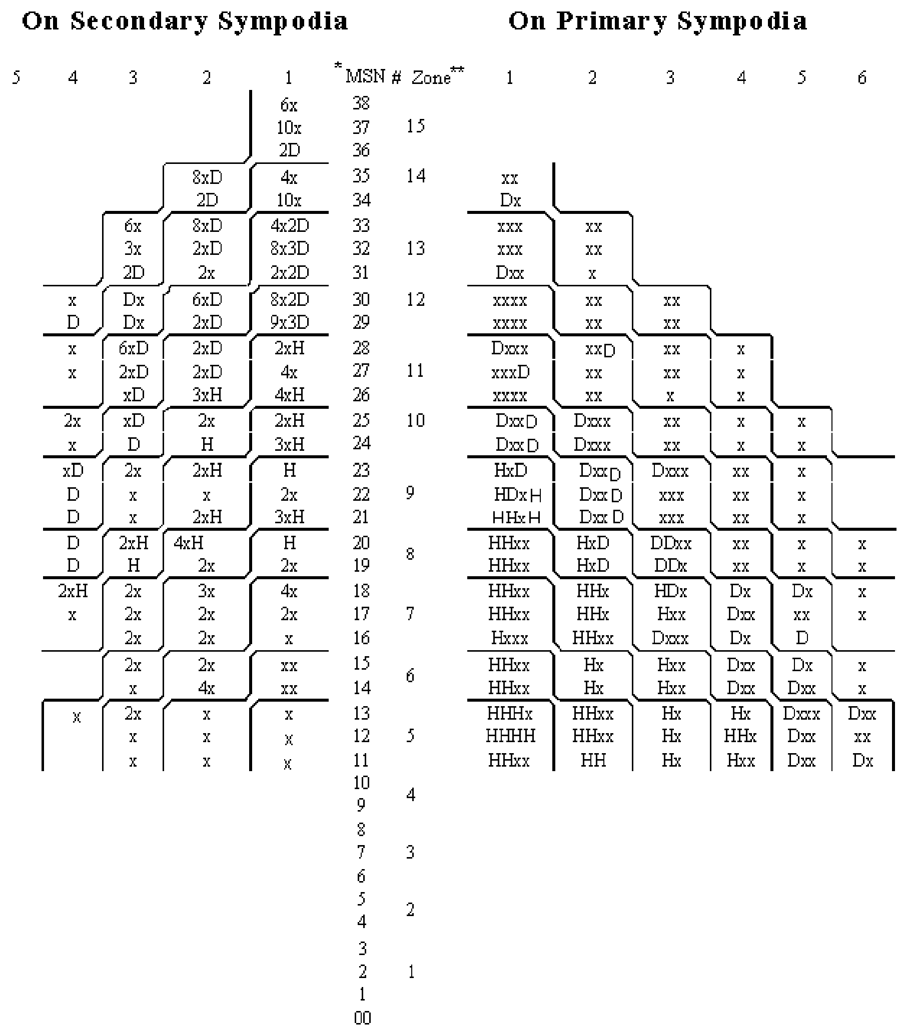


On Secondary Sympodia | *On Primary Sympodia*

Σ	13	12	11	10	9	8	7	6	5	sym	5	6	7	8	9	10	11	12	13	Σ
254	5	14	36	35	51	50	28	25	10	x	5	11	17	21	27	16	17	16	14	144
37	6	10	18	3						D				1	5	22	12	4	2	46
12				8	3					H	2	2	10	8	12	6	5			45
303	11	24	54	46	54	51	28	25	10	Σ	7	13	27	30	44	44	34	20	16	235
											10	25	28	51	54	46	54	24	11	303
										Σ	17	38	55	81	98	90	88	44	27	538

* Main stem node number **Bold numerals denote zone number

Fig. 4. Fruit production efficiency as affected by application of 125 kg K ha^{-1} as KCl in cv. CIM-1100.



Zone Number

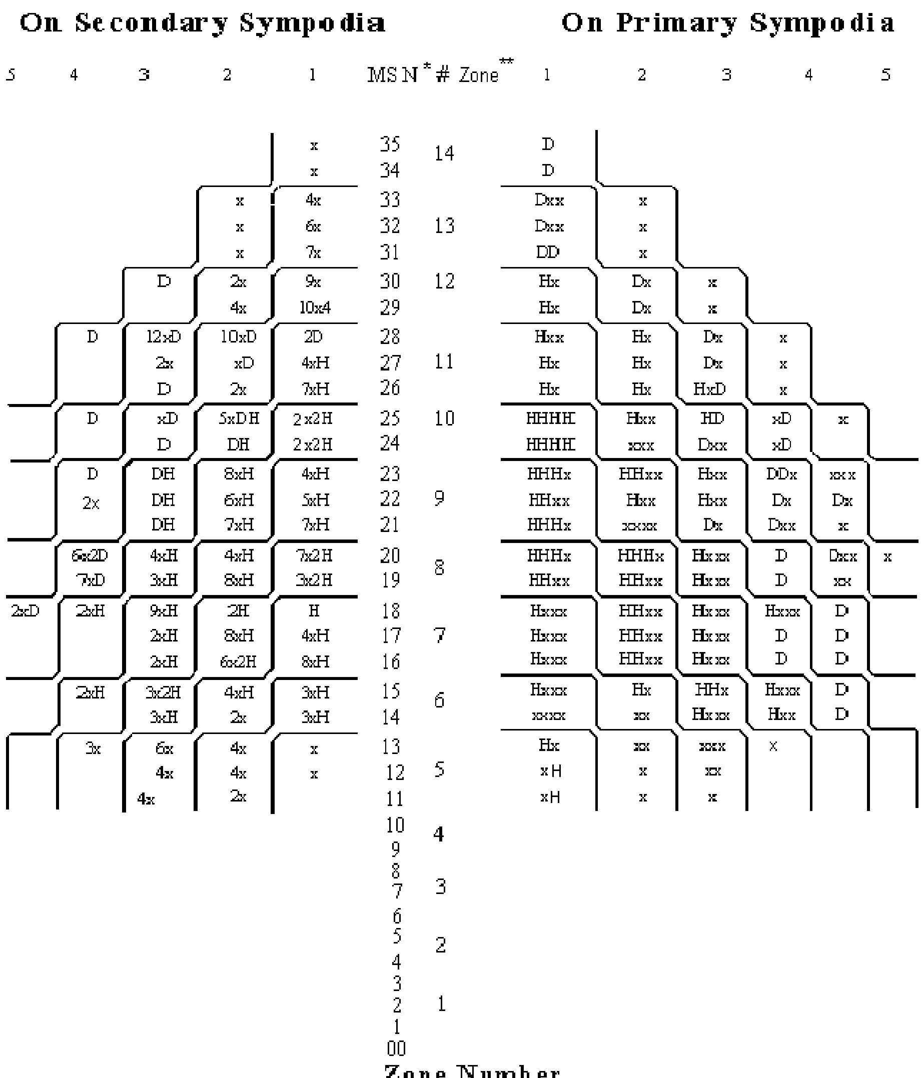
On Secondary Sympodia | *On Primary Sympodia*

Σ	15	14	13	12	11	10	9	8	7	6	5	Sym	5	6	7	8	9	10	11	12	13	14	15	Σ
212	34	30	34	26	16	15	17	12	18	7	3	**x**	3	8	12	16	22	25	34	28	24	17		189
36	8	4	12	10	2							**D**					11	21	7	1	1	1		42
15				1	3	7	3	1				**H**	9	10	10	16	10							55
263	42	34	46	37	21	22	20	13	18	7	1	**Σ**	12	18	22	32	43	46	41	29	25	18		286
													3	7	18	13	20	22	21	37	46	34	42	263
												Σ	15	25	40	45	63	68	62	66	71	52	42	549

* Main stem node number

**Bold numerals denote zone number

Fig. 5. Fruit production efficiency as affected by application of 125 kg K ha^{-1} as K_2SO_4 in cv. CIM-1100.



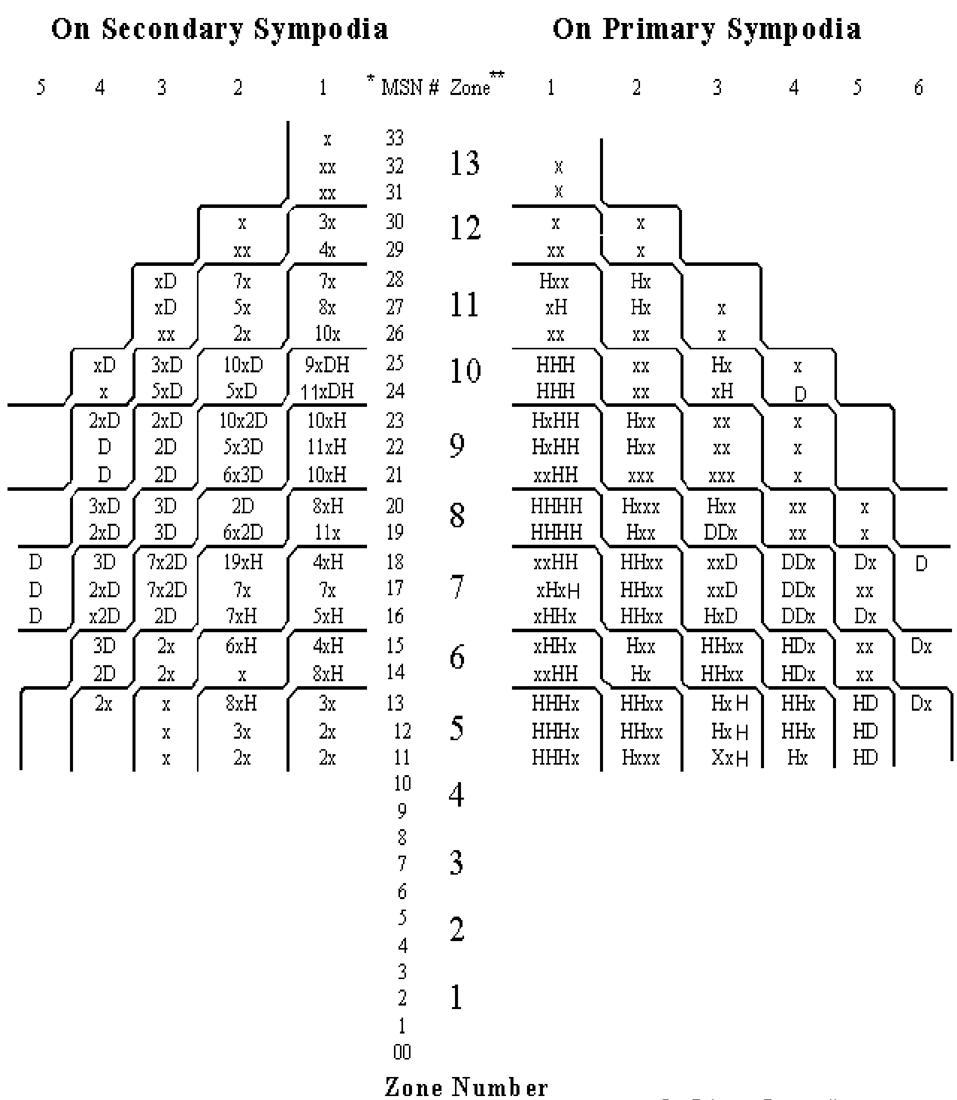
On Secondary Sympodia | *On Primary Sympodia*

Σ	14	13	12	11	10	9	8	7	6	5	Sym	5	6	7	8	9	10	11	12	13	14	Σ
268	5	37	33	31	34	43	35	32	16	2	x	3	11	18	14	21	17	14	15	18	9	140
21	2	3	5	11							D						4	6	7	12	2	31
45			1	7	10	9	12	4	2		H	3	1	4	14	8	14	6	6			66
334	7	40	39	49	44	52	47	36	18	2	Σ		12	22	28	39	35	26	28	30	11	234
												2	18	36	47	52	44	49	39	40	7	334
											Σ	5	30	58	75	91	79	75	67	70	18	568

* Main stem node number

**Bold numerals denote zone number

Fig. 6. Fruit production efficiency as affected by application of 250 kg K ha^{-1} as KCl in cv. CIM-1100.



On Secondary Sympodia | *On Primary Sympodia*

Σ	13	12	11	10	9	8	7	6	5	Sym	5	6	7	8	9	10	11	12	13	Σ
294	15	31	47	42	43	58	26	25	7	**x**	3	11	13	13	16	20	20	14	7	119
58	3	5	12	23	15					**D**					8	4	3	1	1	17
14				2	3	3	3	3		**H**	9	9	13	23	16	9	2	4	1	86
366	18	36	59	67	61	61	29	28	7	**Σ**	12	20	26	36	40	31	29	19	9	222
											7	28	29	61	61	67	59	36	18	366
										Σ	19	48	55	97	101	98	88	55	27	588

* Main stem node number

** Bold numerals denote zone number

Fig. 7. Fruit production efficiency as affected by application of 250 kg K ha^{-1} as K_2SO_4 in cv. CIM-1100.

Table 2. Percentage of bolls per position on sympodia as influenced by potassium nutrition in cv. CIM-1100.

K-Dose Kg ha^{-1}	K-Source	Nodal position along sympodia						
		1	2	3	4	5	6	7
0	---	34	13	15	15	10	---	---
62.5	KCl	34	15	23	16	10	2	---
	K_2SO_4	35	22	21	11	5	3	1
125.0	KCl	37	25	19	10	8	3	2
	K_2SO_4	39	28	15	9	7	2	---
250.0	KCl	41	22	18	10	7	2	---
	K_2SO_4	40	27	16	15	8	3	1

LSD ($p<0.05$)

Nodal position	(N)	0.97**	N x S	1.20**
K-Dose	(D)	0.60*	D x S	0.78**
K-Source	(S)	0.45ns	N x D x S	2.08**
N x D		1.59**		

ns= non-significant at the 0.05, *, ** Significant at the 0.05 and 0.01 level.

The production of sympodial branches, on which first fruiting position was set differed due to K-fertilizer treatments. The crop receiving 250 kg K ha^{-1} retained sympodial branch at node 11 compared to K-unfertilized treatment at node 18. It is postulated that loss of young squares at the beginning of the season occurred because the vascular system is poorly developed, the young fruit had to depend on diffusion to supply assimilates (Constable & Rawson, 1980). A high concentration gradient is required to derive the diffusion process, so local assimilate supply would be indirectly important for square survival. Therefore, any nutrient stress can trigger loss of squares. The young fruit do compete with vegetative growth at this time, and it is important to note that the first fruiting branch has reduced boll survival when compared with subsequent fruiting branches. Loss of later bolls result because the demand of a young boll will often exceed the local supply (Constable & Rawson, 1980). Bridge & McDonald (1987) indicated that improved management practices, the time required to produce a crop of cotton has been shortened considerably. It was attributed that earlier maturity can be enhanced to changes in nutritional management of cotton production. Data of our study support part of this as being due to earlier positioning of bolls at nodes 11 and 12 (flowering at position one).

The percent retention of fruiting forms at the end of season averaged across potassium doses were 38, 22, 18, 13 and 8%, respectively (Table 3). The pattern of boll retention for the third position showed larger reductions than did first position retention. The boll retention under 250 kg K ha^{-1} treatment was 42 and 17% for sympodial nodes one through three, and then decreased drastically. When all retention for sympodial branch positions one through 5 were considered, 250 kg K ha^{-1} treatment showed greater retention at all nodes. There was a consistent increase in retention caused by application of K-fertilizer in first four nodes followed by reductions in the remaining nodes. The larger branches were located on the lower half of each plant. Nearly 70% of branches with at least three sites had a boll at the first three positions, or the first, second or third position only. Kerby *et al*., (1987) have shown similar data with Acala cotton. The crop well supplied with potassium nutrient made an earlier transition from vegetative to reproductive growth. This might have a better coordination of assimilatory capacity with reproductive sink activity as well as making more reproductive development during the time when maximal leaf mass and area were present.

Table 3. Number of harvestable bolls on sympodia in their contemporary zones in cv. CIM-1100.

Treatments		Sympodial node number on main stem											
K Dose [kg ha^{-1}]	K-Source	11-13 (5)	14-15 (6)	16-18 (7)	19-20 (8)	21-23 (9)	24-25 (10)	26-28 (11)	29-30 (12)	31-33 (13)	34-35 (14)	36-38 (15)	Σ
0	-	-	-	1	4	4	2	7	6	3	6	6	39
62.5	KCl	-	-	3	5	13	16	13	4	6	-	-	60
	K_2SO_4	2	11	21	11	8	6	10	5	2	-	-	76
125.0	KCl	2	2	10	9	17	28	17	4	2	-	-	91
	K_2SO_4	9	10	10	16	21	21	7	1	1	1		97
250.0	KCl	3	1	4	14	18	18	12	13	12	2	-	97
	K_2SO_4	9	9	13	23	24	13	5	5	2	-	-	103

( ) Contemporary zone number

LSD ($p<0.05$)				
Zone Number	(Z)	0.61**	Z x S	0.92**
K-Dose	(D)	0.34**	D x S	0.48**
K-Source	(S)	0.28**	Z x D S	1.59**
Z x S		1.13**		

** Significant at the 0.01 level

The application of potassium fertilizer in the form of sulphate of potash showed an edge over muriate of potash in terms of production and retention of harvestable bolls (Table 2). Sulphate of potash caused in lengthening of fruiting branches and retaining more number of fruit on nodal positions along sympodia. The number of main stem node were either unaffected or only slightly affected by the treatments imposed. The crop having good nutrient supply maintains growth for longer period and there is likely to be better co-ordination of assimilatory capacity with reproductive sink activity (Jenkins *et al.*, 1990). The conditions would favour greater retention of fruit in non-stressed cotton crop.

The plant mapping for determining effectiveness of fruiting positions on the sympodia identify differences in harvestable boll number contributing toward yield production under various crop management practices. The node number of first fruiting branch and percentage of bolls retention on different positions along sympodia, may be considered while interpreting data regarding assessing the crop fruit load for estimating yield. These variables can be quantified within season and constructing plant maps at maturity. The number of harvestable bolls set at three first key positions along sympodia may be used as an early indicator of yield potential of cotton crop.

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