A UNIFIED HORMO–NUTRITIONAL CONCEPT OF BOLL SHEDDING IN COTTON[1] /

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Resumen

Los estudios acerca del desarrollo y contenido de nutrimentos en plantas de algodón normales y desyemadas, y aquéllos acerca de los cambios en la actividad de la nitrato-reductasa en diferentes estados fisiológicos, mostraron un patrón común definido en la absorción de los nutrimentos y el desarrollo. Los nutrimentos absorbidos se pierden en cantidades apreciables mediante la emisión de los frutos durante los períodos de floración y belloteo. Dado que el porcentaje de establecimiento de bellotas podría ser incrementado con aplicaciones foliares del ácido naftalen-acético (NAA) y de difosfato de amonio (DAP) durante la más activa fase del crecimiento reproductivo, se propone que la interacción abscisina-auxina y el suministro de nutrimentos, junto con la influencia de los factores ambientales, gobiernan la emisión de las bellotas (belloteo) en algodón.

Introduction

The early work lent considerable support to the nutritional theory of boll shedding, i.e. the cotton plant retained only those bolls which could be adequately supplied with carbohydrates and protein constituents for their growth (12, 19, 22). Eaton and Ergle (16) showed that there were no differences in carbohydrate and nitrogen levels during periods of less or heavy shedding. Spraying with sucrose and urea did not decrease shedding. They proposed that the shedding of cotton bolls is controlled by the ratio of leaf mass to the number of developing bolls and that an auxin-inhibiting material produced in developing cotton bolls counterbalanced the auxin produced by the plant causing shedding. Subsequent work showed that abscisic acid produced in the ovary wall of the cotton boll, at certain concentrations, caused shedding during about the first fortnight after anthesis (1, 7).

According to growth models for cotton showing balance sheets of supply and demand for carbohydrates and nitrogen, in a normal field crop boll-growth is limited by photosynthate or nutrients (11, 21). An attempt was therefore made to find out how foliar applications of auxin and nutrients influence boll setting in cotton. It is also known that loss of fruiting bodies due to shedding is compensated by development of new buds on other fruiting branches. To obtain more information on boll shedding, the effects of disbudding on nutrient uptake and changes in sugar content were also studied.

Material and methods

For studies on the effect of disbudding, plants of variety MCU.5 (*G. hirsutum* L.) were raised in large pots adequately manured and watered regularly. There were two treatments: (1) control (normal plants) and (2) disbudded plants. In plants set aside for disbudding, all incipient buds, when formed, were removed throughout their growth i.e. until all the bolls in control plants were burst. The samples for dry weight determination and chemical

1 Received for publication 22 September 1980

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analysis were taken from normal as well as disbudded plants, when normal plants were in (i) early flowering stage (65 days), (ii) peak flowering (90 days), (iii) early boll bursting (115 days) and (iv) harvesting stage (145 days) i.e. second picking of seed cotton.

For studies on boll setting, the varieties taken were PRS 72, MCU.5 (both *Gossypium hirsutum* L.) and Suvin (*Gossypium barbadense* L.). The treatments were (1) control (untreated) (2) naphthalene acetic acid (NAA) and (3) diammonium phosphate (DAP). There were 10 pots per treatment. An aqueous solution of NAA 10 parts per million was sprayed at the rate of 40 ml per plant after about 10 flowers were formed and the treatment repeated after 3 weeks. One per cent aqueous solution of DAP was sprayed in the same manner as NAA. The observations on number of buds and bolls shed were recorded daily. The experiment was conducted in the net-house from mid-August to February.

Nitrogen and phosphorus were estimated according to standard colorimetric procedures. Total sugars were estimated by Somogyi's method (33). The results in Figure 1 are expressed on per plant basis. The procedure of Eckerson (18) was followed for nitrate reductase activity which is expressed as mg of nitrate nitrogen per 100 g fresh weight of tissue.

For further studies a short duration variety C-1412 (*G. hirsutum* L.) was raised in the field under rainfed conditions. With the onset of north-east monsoon, the crop was sown in the first week of October and harvested by mid-February. The experiment was designed on randomised blocks, with a plot size of 6.3 m x 3.6 m per treatment. There were three replicates. The treatments were (1) control, (2) water spray, (3) NAA 20 ppm, (4) DAP 3%, and (5) NAA followed by DAP. The spray fluid was applied at the rate of 800 litres per hectare during the afternoons. For the fifth treatment, after the first application of NAA, DAP was sprayed after an interval of 10 days. The second application of NAA was therefore given after 20 days (of the first application) and followed by the second application of DAP after 10 days. The second and the third treatments were given in the same manner as in the pot experiment. The observations on shed fruiting forms, boll number and yield of seed cotton were recorded on six plants randomly selected per treatment in each replicate.

The bolling period for effective applications of the treatments was from the 80th day after germination to the 120th day for vars. MCU.5 and Suvin and from the 60th to the 90th day for vars. PRS 72 and C 1412.

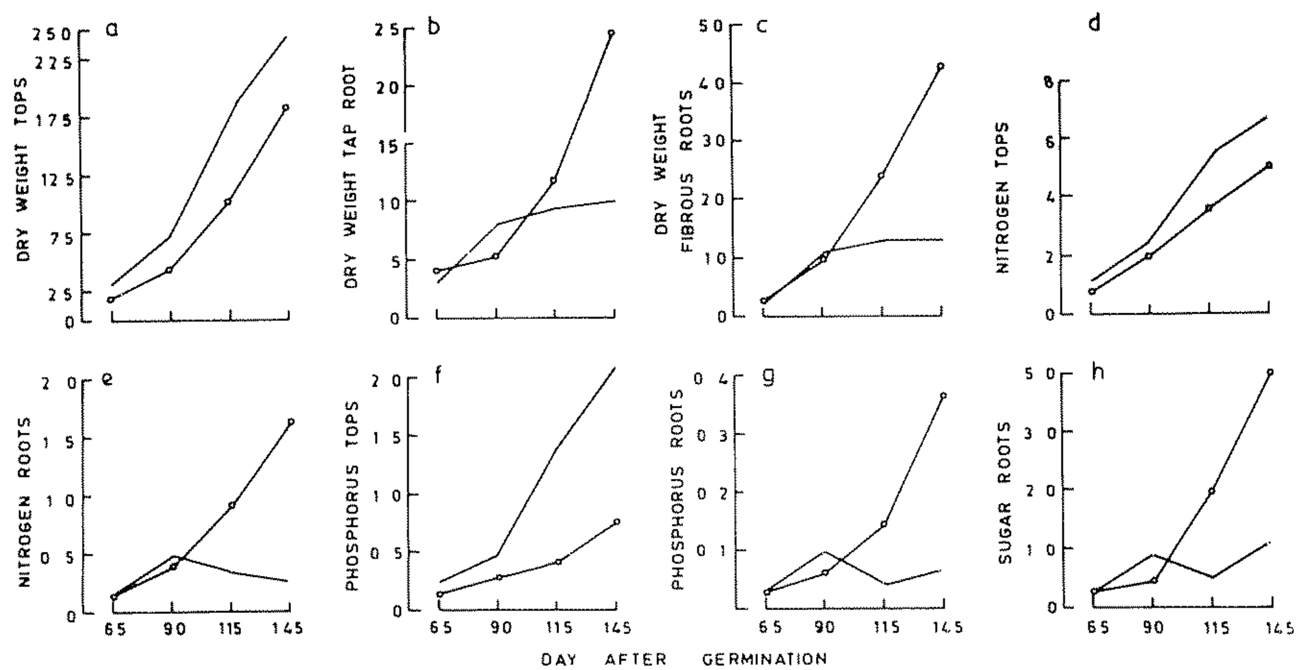

Fig. 1. Accumulation of dry matter, nitrogen phosphorus and sugar content in normal and disbudded plants. The continuous lines indicate normal plants, whereas lines joined by open circles indicate disbudded plants

Results and discussion

Effect of disbudding on dry matter, nitrogen and phosphorus contents

It will be seen from Figure 1a that the normal plants accumulated dry matter at a faster rate than the disbudded plants and had much higher dry weight at maturity. The growth of roots in normal plants practically ceased after the peak flowering stage, whereas in treated plants there was a steep rise in dry weight (Figures 1b and c). In earlier experiments disbudding was resorted to at certain stages and for a limited period with a view to improve yield and it was found that disbudded plants had a higher dry weight of their aerial parts (10, 13, 14, 15, 20, 32). In the present experiments, the dry weight of aerial parts of the disbudded plants was sufficiently lower than the control, whereas the weight of roots was much higher. It will also be seen that the total dry weight (including tops and roots) of disbudded and control plants was practically the same. This may be attributed to continuous disbudding which promoted excessive development of the root system.

The total nitrogen content of the aerial parts of the control plants was higher than that of the disbudded plants at maturity (Figure 1 d). The roots of disbudded plants, on the contrary, contained more nitrogen (Figure 1 a). The results are in variance with those of Dale (10) because of differences in dry weight. Compared with nitrogen, total phosphorus content of the aerial parts of the control plants was much higher due to its entry into seeds. Like nitrogen, the roots of disbudded plants had very high levels of phosphorus after the peak flowering stage (Figures 1 f & g).

Loss of nutrients through boll shedding and retention of bolls as effected by nutrient/hormone sprays

Physiologically shed bolls of MCU.5 had per g dry weight 10 mg less nitrogen than normal bolls. In Suvin the losses were less than half for 3 to 5 day old bolls but 10 day old bolls showed the same trend as MCU.5 (Table 1). On an average the shed bolls of MCU.5 contained 1.66 mg/g of phosphorus compared with 2.37 mg/g in normal bolls. The 3 day old shed bolls of Suvin represented a comparatively higher loss of phosphorus than those of MCU.5. The normal 5 and 10 day old bolls had higher phosphorus content and the quantities lost through shedding were also higher (Table 2).

Table 1. Nitrogen mg/g dry weight of bolls.

	Days after anthesis					
	3		5		10	
Variety	Normal	Shed	Normal	Shed	Normal	Shed
MCU.5	29.4	19.7	30.5	20.4	31.9	20.6
Suvin	27.0	11.5	26.2	11.0	26.6	16.3

Table 2. Phosphorus mg/g dry weight of bolls.

	Days after anthesis					
	3		5		10	
Variety	Normal	Shed	Normal	Shed	Normal	Shed
MCU.5	2.28	1.76	2.39	1.47	2.45	1.75
Suvin	1.87	1.49	3.92	2.00	3.91	2.69

It will be seen from Table 3 that there was a considerable increase in retention of bolls in the three varieties treated with naphthalene acetic acid. The increase was slightly more in plants sprayed with diammonium phosphate. Both the treatments caused reduction in shedding due to physiological causes. The increase in yield of seed cotton through increase in the number of bolls set by naphthalene acetic acid had long been reported by Bhatt and Date (3) in *G. arboreum* cotton and subsequently confirmed by Negi and Avatar Singh (26) and Bhardwaj and Santhanam (2) in *G. hirsutum* cottons. The earlier negative report on the effects of naphthalene acetic acid on *G. hirsutum* cotton appears to be due to inadequate information then available about precautions to be taken to spray the hormone and comparatively higher susceptibility of American cottons to boll worms (4). However, further work by Bhatt (6) showed how *G. hirsutum* and *G. barbadense* cottons respond favourably to naphthalene acetic acid when proper precautions are taken at the time of applications. This was followed by a number of confirmatory reports on increase in number of bolls and ultimately the yield of seed cotton through naphthalene acetic acid in *G. hirsutum* cottons by Mukharji (24), Padaki *et al.* (27), Chowdappan and Morachan (9), Sankaran and Balasubramanian (3), Murty *et al.* (25), Rao *et al.* (28) and Chaudhari and Bathkal (8).

Varma (34) observed in *G. hirsutum* cotton that abscisic acid applied exogenously, either to intact flower buds/bolls or boll explants, promoted their abscission. Naphthalene acetic acid not only reduced abscission but also could eliminate completely the promotive effect of abscisic acid on abscission.

Environmental stresses raise abscisic acid levels in plants (23). The external applications of growth regulators would therefore help reduce abscisic acid level and regulate growth.

Foliar applications of low concentration sprays of diammonium phosphate during flowering and bolling in *G. hirsutum* cotton have been found to retain a higher number of bolls and increase the yield of seed cotton (5). Sato (31) showed how foliar application of phosphorus accelerates nutrient uptake and improves growth due to a higher rate of carbon assimilation.

The results of hormone/nutrient applications were further confirmed under field conditions. It will be seen from Table 4 that both NAA and DAP were equally effective in reducing physiological shedding and retaining more bolls. When NAA was followed by DAP there was further reduction in shedding and increase in boll setting. These treatments not only increased the boll weight but enhanced the yield of seed cotton also.

A comparison of the patterns of root and shoot growth showed that after the peak flowering stage, the growth of roots of the normal plants practically ceased followed by a steep rise in dry weight of the roots of disbudded plants. At this stage not only nitrogen but phosphorus content of the roots of normal plants also showed a downward trend. It was interesting to note that on per plant basis sugar content of the roots of the normal plants decreased from peak flowering onwards with a rise in sugar content of disbudded plants (Figure 1 h). Eaton and Joham (17) have shown that nutrient uptake in

Table 3. Number of fruiting forms shed and the number of bolls retained per plant.

Variety	Treatment	Shed due to pest attack	Shed due to physiological causes	Intact bolls
PRS 72	Control	16	22	12
	NAA	15	17	19
	DAP	15	17	20
MCU 5	Control	20	24	16
	NAA	16	20	26
	DAP	16	18	28
SUVIN	Control	18	30	20
	NAA	26	18	24
	DAP	14	24	24

Table 4. Number of fruiting forms shed per plant and yield characters in var. C. 1412 (*G hirsutum*).

Treatment	Shed due to pest attack	Shed due to physiological causes	Bolls per plant	Boll weight, g (seed cotton)	Yield per plant, g	Yield per plot, g
Control	5 3	6.1	4 0	2 50	10 40	204 3
Water spray	5 5	6.0	4.0	2 47	13.03	261 6
NAA	5.0	3.4	7.4	2 87	21 53	385.0
DAP	4 8	3.2	7.1	2 90	20 20	470.8
NAA alternated with DAP	5 0	2 5	8.5	3 03	25 67	620.8
C D. at 5%				0 504	10 65	219.8

cotton is slowed down after the peak flowering stage because of less quantities of sugars translocated to roots as the developing bolls are a major sink for the utilisation of carbohydrates. In their studies on translocation of labelled sucrose Sabbe and Cathey (29) detected radio-activity in the roots of the cotton plant during vegetative growth whereas during flowering and bolling the label was concentrated more in the fruiting parts. In the present experiment, when plants were prevented from entering into the reproductive phase, their root growth was accelerated. The mean length and girth of the tap roots of disbudded plants were 216 cm and 2.8 cm as compared with 120 cm and 1.4 cm respectively, in the normal plants.

It will be seen from Table 5 that nitrate reductase activity in the roots of the normal plants was maximum at initial flowering, decreased at subsequent stages and was quite low when the plants were ready for the first picking of seed cotton. In disbudded plants the activity was comparatively higher in fibrous roots at initial flowering and in main roots during peak flowering. It is also known that maximum absorption of nutrients takes place during peak flowering and bolling. The cotton plant also loses the maximum number of bolls through physiological shedding and pest attack during these stages resulting in considerable loses of the absorbed nutrients. Dale (10) found that disbudding for 13 weeks had an adverse effect on yield; for although more bolls were set on treated plants than on controls, these were small and of little commercial value. It would thus be seen that during reproductive phase the period between first bloom and opening of the first boll is the most crucial when auxin-abscisin balance as well as nutrient availability determine boll retention. Therefore not only auxin sprays but nutrient sprays also help retain more number of bolls during this period (Tables 3 and 4). Even during peak flowering nitrate reductase activity was half of that recorded at initial flowering indicating less turnover of nitrogen. It is interesting to note, in this context, that even in disbudded plants the activity of nitrate reductase was more or less the same as in normal plants, indicating a definite common pattern during different stages of growth.

The setting and shedding of bolls by the cotton plant is therefore governed by both auxin-abscisin

Table 5. Nitrate reductase activity in var. MCU.5.

	Main root		Fibrous roots	
	Control	Disbudded	Control	Disbudded
Initial flowering	0.650	0.675	0.550	0.770
Peak flowering	0 290	0.500	0.290	0.300
Early boll opening	0.200	0.250	0.170	0.170
First picking	0 125	0 125	0.050	0.086

interaction and nutrient supply during its active phase of reproductive growth. These two processes, which are complementary, operate in differing degrees depending upon weather and soil factors during crop growth, and together determine the number of bolls set or shed.

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Reseña de libros

BUTLER, B. E. Soil Classification for Soil Survey. Oxford University Press. England. 1980. 129 p.

El autor, distinguido especialista en edafología, con amplia experiencia en el reconocimiento y mapificación de suelos de Australia pretende, en este pequeño volumen, desarrollar un procedimiento relativamente sencillo para elaborar una clasificación de suelos aplicable a una área particular que se esté reconociendo y mapificando, y que a la vez pueda relacionarse con una clasificación regional o nacional, de manera que se facilite el intercambio de experiencias y resultados experimentales.

En el primer capítulo de la obra se analizan los diversos aspectos conectados con la naturaleza de un reconocimiento de suelos; se comienza por establecer un principio que puede parecer elemental y casi obvio, pero que se olvida más de las veces de lo que fuera de desearse: el de que antes de comenzar un trabajo de esa naturaleza se debe clarificar el propósito para el cual se va a hacer el mapa de suelos; "la primera obligación del reconocedor de suelos, dice el autor, es confirmar que uno o más grupos importantes de usuarios de la región, necesitan conocer la distribución de diferentes clases de suelos dentro del área que interesa." Partiendo así del hecho de que hay un problema especifico, el reconocedor tratará de determinar cuáles propiedades o aspectos del comportamiento del suelo están causando el problema o tienen relación con él; éstas serán las propiedades útiles o importantes de separar y localizar. No sería lógico, por ejemplo, que luego de hacer una mapificación compleja y detallada de los suelos, se descubriera que la dificultad con que se enfrentan los usuarios se deriva únicamente del exceso de acidez de los suelos, la cual podría haberse "mapeado" independientemente en un tiempo mucho más reducido, con menos trabajo y menos costo. A la vez, el reconocedor debe aceptar sus propias limitaciones y tener plena conciencia de que él no está tratando de resolver el problema (pues esta es la labor de agrónomos, ingenieros o veterinarios), sino que apenas se espera que determine la distribución dentro del área de las propiedades del suelo que afectan la situación, las registre o anote y las presente utilizando un mapa de clasificación y su leyenda respectiva. Su papel, por lo tanto, es el de **predecir** o, más claro, el de suministrar una herramienta para que los encargados de solucionar los problemas puedan informarse sobre las condiciones de los suelos en el área, sin tener que ir al campo a determinarlas.

La clasificación u ordenación de individuos en grupos diferenciados, con características importantes para los usuarios, es por lo tanto, la base del reconocimiento. Para llevarlo a cabo se comienza por revisar las condiciones generales del área del proyecto: su topografía, geología, ecologia y los estudios de suelos que se hayan llevado a cabo; se le da especial importancia al "problema" y su relación con un suelo determinado o con otros factores locales; luego se genera una lista provisional de clases de suelos para el área del proyecto, a través de las observaciones en numerosos puntos, de las similitudes y diferencias en las propiedades que se han seleccionado como importantes; esta lista se confronta con una muestra del conjunto total de datos de propiedades de los perfiles en el área, para ir asignando los diferentes suelos a las clases propuestas, las cuales luego se comparan para estar seguros de que ellas son diferentes unas de otras y están asociadas con propiedades importantes y muy particularmente con los factores de suelo relacionados con el "problema". A través de pruebas empíricas se refinan las clases suprimiendo unas, juntando otras, teniendo siempre en mente la utilidad para los usuarios, del mapa final de suelos.

Este procedimiento esquematizado en los párrafos anteriores, se explica paso a paso en el libro que comentamos en forma suficientemente detallada para permitir su utilización efectiva hasta desembocar en la preparación de la clave final de clasificación y la tabulación de la leyenda o explicación que acompaña al mapa de suelos.

En el capítulo final se describen varios de los más conocidos sistemas de clasificación a nivel nacional o mundial, con el propósito, sin duda, de contribuir a darle perspectiva a los reconocimientos locales los cuales tienen que ser susceptibles de compararse con los realizados en otras latitudes, a través de su inserción en esquemas más amplios.

El pequeño volumen incluye una bibliografía aceptable y sendos índices por autor y por materia.

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