# PHYSIOLOGICAL APPROACH TO THE CONCEPT OF PLANT-TYPE IN COTTON[1] /

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## Resumen

*Se sugiere un tipo ideal de algodón para regiones algodoneras de secano en las cuales se presenta condiciones adversas tales como alta nubosidad, pocas horas de luz y distribución irregular de la lluvia.*

*Una planta de estructura compacta con follaje abierto, hojas relativamente pequeñas bien inclinadas para interceptar un máximo de luz y con movimiento heliotrópico, simpodias pequeñas con internudos múltiples y un sistema radical profundo, se considera como eficiente. Se programa utilizar una planta semienana, con no más de un metro de altura que se puede sembrar en espaciamiento cerrado. Se prefiere una planta con hojas de empalizada grueso en vez de parénquima esponjoso y epidermis delgada para resistir a la sequía, de período corto y de maduración temprana de manera que completa su ciclo de vida entre 120 y 130 días.*

*La planta propuesta se espera que produzca una cantidad adecuada de materia seca, un crecimiento balanceado altos coeficientes de fructificación y una utilización económica de nutrimentos.*

## Introduction

Engledow and Wadham (18) felt that plant characters which control yield should be found out and synthesized into one plant-form at an optimum level. The reseachers started in Japan to prevent lodging in rice grown with high fertilizer applications, and subsequent understanding of light relations in plant communities led to the concept of an ideal plant type (3, 4, 21, 29), giving rise to varieties with phenomenal production (2).

Donald (16) emphasized that rapid progress could be achieved if plant breeders aimed to produce ideotypes with specific combinations of characteristics favourable to photosynthesis, growth and yield. He felt that the wheat ideotype he depicted was not likely to be developed in breeding programmes based on selection for yield under prevailing agronomic practices in view of lower per plant yield, competition from other genotypes and different mechanical handling. Nevertheless he considered exploitation of plant ideotype a logical step twards new levels of yield which should be pursued with imagination.

For the wheat ideotype to be grown under irrigated conditions Donald (16) suggested a uniculm habit with fewer erect leaves which will not shade each other and with more seminal roots. On the other hand, asana, as quoted by Swaminathan (26), proposed horizontal leaves for intercepting and retaining dew, a branched ear and a deep root system for raingrown wheat. The yield therefore would be affected in many ways by a particular physiological or morphological trait depending upon other characteristics, environment and agronomic practices. Bhatt *et al.* (5, 6, 7, 8, 9, 10, 11, 12) studied several aspects of the cotton plant to elicit desirable physiological traits for crop improvement.

With the growing limitations of available fresh water, energy, nitrogen and other chemical inputs, mineral oil, and the efficiency of phosphorus use which is assuming increasing importance, the physiological basis of yield needs to be adjusted. In India,

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nearly 75% of the cotton crop is raingrown. The rainfall pattern varies from low to satisfactory or assured conditions, at times with no rains in the latter part of the monsoon. Based on the available data an attempt is made here to visualise a plant-type that could not only raise the present low level of yield of raingrown cotton but stabilize it at an acceptable level.

Unlike rice and wheat where source and sink are well fixed and function within reasonable boundaries, the morphological frame of the cotton plant varies from the extreme short branch to long sympodial and monopodial branches with secondary sympodia. The source-sink relationship is often disturbed as bolls (cotton fruits) are lost due to physiological factors or pest attack.

## Materials and methods

All observations were recorded on field grown cotton plants. The leaf area index was measured by the formula of Ashley *et al.* (2). The net assimilation rate was calculated according to the procedure of Watson (30).

In experiments with PIX (1-1-dimethil-piperidinim-chloride) an aqueous solution of 60 ppm concentration of this chemical was given as foliar spray at the rate of 300 litres/hectare, 80 days after germination when the crop was in early flowering phase.

For all experiments the row spacing for different varieties was kept at 60 cm. The plants within the row were spaced at 30 cm except the compact types which were spaced at 15 cm. Different spacings were given (see under investigation and discussion) when net assimilation rate was studied in relation to spacing.

The varieties studied were: MCU 1, MCU 5, MCU 7, PRS 72, C 1412, B 1007, B 147, Indore 1, 320 F, Okra, G 67, IAN 579, SRT 1 (all *Gossypium hirsutum* L.), K 7 (*Gossypium arboreum* L.), and Varalaxmi, an interspecific $F_1$ hybrid (*G. hirsutum* x *G. barbadense*).

## Results and Discussion

### Canopy, leaf area index and growth

The branching habit and leafiness which determine the canopy were compared in two morphologically contrasting cultivars MCU 5 and PRS 72 (both *G. hirsutum*). The former is a traditional type with the usual plant structure whereas the latter is characterized by the complete suppression of monopodial branches and the reduction in the length of the second internode of the fruiting branch which ends in a cluster of two or three flowers.

Though PRS 72 had less number of leaves per plant and lower LAI than MCU 5, it had many expanding leaves (Table 1). According to Hopkinson (19) the main contribution to photosynthesis and ultimately to increase in dry weight comes from those leaves that are rapidly expanding, that is, those between one quarter and three quarters of the final area. It will be seen from Table 2 that because of the short branch habit most of the leaves of PRS 72 intercept more sunlight.

Ashley's studies (1) showed that much of the vegetative growth commonly present on the cotton plant is ineffective in supplying metabolites for fruit development, and excess vegetative growth was found by Bhatt (5) to reduce the fruiting coefficient in cotton. Since the seed cotton yield/ha of PRS 72 and MCU 5 was the same, a smaller but unshaded or much less shaded leaf area of an open canopy appeared more effective than a large area made up of many shaded leaves in intercepting sunlight and may make up for better plant efficiency with low LAI.

In another experiment a compact semi-dwarf cultivar C 1412 was compared with two semi-compact cultivars MCU 7 and SRT 1 under very low rainfall conditions.

Though LAI of C 1412 during reproductive phase was lower than the other two cultivars, it yielded nearly four times more. The variety C 1412 has shorter duration of 125 days when compared

Table 1. Number of leaves, one quarter to three quarters expanded two weeks before maximum LAI.

| | Leaves/sq. meter | | Expanding leaves (%) | Maximum LAI | Yield of seed cotton (kg/ha) |
|---|---|---|---|---|---|
| | Expanding | Total | | | |
| MCU 5 | 232 | 837 | 27 7 | 5.5 | 2 780 |
| PRS 72 | 162 | 289 | 56 1 | 3.0 | 2 769 |

with 160 days of MCU 7 and 150 days of SRT 1 besides comparatively open canopy and other desirable features to be discussed hereafter (Table 3). The reduction in leaf area at maturity also facilitates picking of seed cotton.

How variations in LAI through changes in plant populations affected net assimilation rate (NAR) and yield was further investigated. The cultivars taken for the study were G 67, a bushy type giving rise to a large canopy and IAN 579 a compact one.

Unlike G 67, the NAR of IAN 579 increased with closer spacing and higher plant density (Table 4). Except under the widest spacing the yield of G 67 remained practically the same, but that of IAN 579 increased significantly with the closest spacing and maximum LAI and NAR. Thus for IAN 579 dependence of NAR on LAI was generally positive and that in a compact type with open canopy even a little denser arrangement of the leaves may not interfere with their functional activity.

## Production of dry matter and fruiting coefficient

The expression of early vigour helps establish proper crop stand in the field. The compact type C 1412 was compared with the normal cultivar MCU 5

Table 2. Percentage of sunlight intercepted at maximum LAI.

| | NODES | | | | |
|---|---|---|---|---|---|
| | 4 to 7 | 8 to 12 | 13 to 16 | 17 to 19 | 20 to 23 |
| MCU 5 | 25 | 54 | 56 | 68 | 90 |
| PRS 72 | 72 | 77 | 90 | 100 | 100 |

Table 3. Range of LAI during growth, and yield of seed cotton.

| Cultivar | Flowering and bolling | Maturity | Yield (kg/ha) |
|---|---|---|---|
| C 1412 | 3.2 – 4.1 – 4.0 – 4.0 – 3.5 | 1.5 | 5.89 |
| MCU 7 | 5.4 – 5.6 – 5.2 – 3.9 – 3.5 | 2.4 | 1.53 |
| SRT 1 | 5.0 – 5.2 – 5.6 – 4.6 – 4.0 | 3.3 | 1.41 |

Table 4. Maximum LAI with corresponding NAR* and yield of seed cotton kg/ha under different spacings.

| | | Spacings | | | |
|---|---|---|---|---|---|
| Cultivar | | 1.2 x 0.3 m | 1.2 x 0.6 m | 1.2 x 0.9 m | 1.2 x 1.2 m |
| G 67 | LAI | 7.5 | 6.0 | 5.2 | 4.0 |
| | NAR | 0.0094 | 0.1229 | 0.0912 | 0.1166 |
| | Yield | 2344 | 2362 | 2273 | 1972 |
| IAN 579 | LAI | 4.8 | 3.8 | 2.0 | 2.0 |
| | NAR | 0.4512 | 0.2842 | 0.2363 | 0.2662 |
| | Yield | 3640 | 3332 | 3101 | 3125 |

* Regression values

S.E. for cultivars 91.6; for spacings 88.1
L.S.D. (P = 0.05) for cultivars 315; for spacings 255

and the interspecific $F_1$ hybrid Varalaxmi known for high degree of heterosis for growth and yield.

When compared with MCU 5 and Varalaxmi, 30 days after sowing C 1412 was taller and its leaf area was practically the same as MCU 5 (Table 5). At the 45th day C 1412 produced the same quantity of dry matter as Varalaxmi in spite of lower leaf area, whereas MCU 5 with its comparable leaf area had much lower dry weight.

The fruiting coefficient or yield capacity also termed as vegetative efficiency is defined as the quantity of seed cotton produced per 100 g dry matter of the whole plant (13). Dastur (14) found that yield capacities of Indian cottons were not lower than those grown elsewhere and attributed their lower yields to production of low dry matter. In view of wide variations in production of dry matter and yield of cotton cultivars growing in different agro-climatic conditions, the fruiting coefficients of these cultivars were studied in comparison with the performance of a compact type PRS 72.

The cultivar MCU 1 with the usual plant structure was compared first with PRS 72. Since the fruiting branches of the latter do not attain lateral bushy growth it was spaced at 15 cm within the row and the former at 30 cm as usual. Both cultivars were spaced at 60 cm between the rows. Thus per unit area basis, the population of PRS 72 was twice that of MCU 1.

Both cultivars were given 12 different fertilizer treatments to increase growth under irrigated conditions and to study the dependence of yield on dry matter production. The mean yield of these treatments for PRS 72 was 29.1 g and the mean dry matter 63.0 g on per plant basis. The correlation coefficient between these two parameters was 0.9342 and significant at 1 per cent level. The regression coefficient of X (dry matter) on Y (yield) was also highly significant and gave the following equation.

$$Y = -3.37 + 0.51565\ X \quad (1)$$

This showed that for every increase in one gram of dry matter there was a proportional increase of 0.51565 g of seed cotton.

In MCU 1 mean dry weight and yield per plant were 156.5 g and 47.1 g respectively. The correlation coefficient was 0.82850 and the equation for linear regression was:

$$Y = 15.693 + 0.20065\ X \quad (2)$$

Thus with an increase of one gram of dry matter in MCU 1 the yield of seed cotton increased by 0.20065 g.

The curves of the type $Y = a + bX + cX^2$ when fitted for the two cultivars showed that the behaviour of MCU 1 after giving 54 g of yield per plant is erratic, whereas a more or less linear relationship exists between dry matter production and yield in PRS 72.

Amongst the cultivars growing at different locations, Indore 1, B 147 and MCU 1 have the same fruiting coefficient and yielded in proportion to the dry matter produced (Table 6). But 320 F even with more nitrogen did not improve its fruiting coefficient in spite of large quantities of dry matter. The yield capacity of the traditional types is limited as leaves and branches through their lateral bushy growth contribute largely towards the production of excessive dry matter. On the contrary, the vegetative and reproductive growth of the compact type PRS 72 appeared to be balanced as it gave more seed cotton in proportion to total dry matter. For the same quantity of seed cotton yielded by PRS 72, the cultivars like MCU 1 produced 3 500 kg extra dry matter and, though the yield of 320 F was half that of PRS 72 it produced large quantities of dry matter mostly through vegetative growth.

That reduction in dry matter within reasonable limits does not impair the yield capacity could be seen from the effect of growth regulating chemicals on cotton. Bhatt (7) has shown that when excessive

Table 5. Early vigour for growth.

| Cultivar | 15 days | | 30 days | | | 45 days | |
|---|---|---|---|---|---|---|---|
| | Dry matter | Height | Dry matter | Height | Leaf area | Dry matter | Leaf area |
| Varalaxmi | 0.178 | 9.8 | 1.28 | 18.1 | 189.0 | 4.95 | 564.5 |
| MCU 5 | 0.140 | 10.6 | 1.09 | 16.1 | 149.7 | 2.75 | 420.5 |
| C 1412 | 0.130 | 8.6 | 0.82 | 24.3 | 142.0 | 5.18 | 485.2 |

bushy growth of cotton cultivars is cut to size by cycocel-treatment, seed cotton yield increases.

Application of Pix not only reduced the height but dry matter per plant also (Table 7). More number of bolls were retained with consequent increase in yield of seed cotton. As the dry weight of vegetative parts decreased there was an increase in the fruiting coefficient. It is interesting to note that the total dry weight involving the weight of vegetative parts and seed cotton for the controls and Pix-treated plants of the two cultivars was the same. This would indicate better partitioning of the photosynthate for economic yield in Pix-treated plants.

### Heliotropic movements of leaves

The cotton plants growing under natural conditions in the field were found to turn their leaves in the direction of the sun. There appeared to be genotypic differences as these heliotropic movements of leaves were very conspicuous in C 1412 and less perceptible in other varieties. The cotton varieties exhibited these leaf movements by altering the angle between the petiolar joint and the lamina according to the movement of the sun. Several young and expanding leaves at the upper nodes were seen bending towards the sun with their petioles curved in the middle.

The changes in leaf-movements were recorded during the flowering period (Table 8). On the 1st node the leaf angle in C 1412 increased by 30° in the evening when compared with 10° in MCU 5. The changes on the 2nd node were more or less similar in the two varieties. The angle of the main stem leaf in MCU 5 on the 3rd node increased more than that of C 1412. But the sympodial leaf in C 1412 on the same node nearly turned a right angle with the difference of 80° in the evening. The angular changes of the main stem leaves were similar on the 4th node as a decrease was observed in MCU 5 and an increase in C 1412. On the 5th node the trend for the main stem leaves of the two varieties was similar as on the 4th. The first sympodial leaf exhibited no movement and the second showed practically no change in MCU 5. But these leaves in C 1412 changed their angles by 20° and 40° respectively. On the 6th node the main steam leaf of MCU 5 remained in the same position but that of C 1412 decreased its angle by 10°. The 1st sympodial leaf in C 1412 increased its angle by over four times that of MCU 5 in the evening. The second sympodial leaf in MCU 5 showed a perceptible change by increasing its angle whereas a decrease was noticed in C 1412.

Table 6. Total dry matter and seed cotton yield (kg/ha).

| Cultivar | Location | Dry matter | Yield | Fruiting coefficient |
|---|---|---|---|---|
| 320 F | Abohar (northern India) | 6 744 | 1 176 | 0.17 |
| 320 F (N 150) | – do – | 7 193 | 1 319 | 0.18 |
| Indore 1 | Indore (central India) | 3 153 | 820 | 0.26 |
| B 147 | Amaravati (central India) | 3 962 | 992 | 0.25 |
| MCU 1 | Coimbatore (southern India) | 8 995 | 2 458 | 0.27 |
| PRS 72 | – do – | 5 488 | 2 626 | 0.47 |

Table 7. Effect of Pix on growth and yield per plant.

| Treatment | Height (cm) | Dry weight (g) | Number of bolls | Seed cotton yield (g) | Fruiting coefficient |
|---|---|---|---|---|---|
| | | | SUMAN | | |
| Control | 125.3 | 125.7 | 11.0 | 40.3 | 0.24 |
| Pix 60 ppm | 99.2 | 102.1 | 17.0 | 62.3 | 0.37 |
| | | | MCU 5 | | |
| Control | 107.6 | 120.2 | 10.0 | 35.2 | 0.22 |
| Pix 60 ppm | 82.6 | 100.7 | 17.0 | 59.1 | 0.36 |
| L.S.D. at 5% | 3.17 | 15.7 | 3.16 | 17.17 | |

**Table 8. Changes in leaf-inclination.**

| Node number from above | MCU 5 | | C 1412 | |
|---|---|---|---|---|
| | Morning | Evening | Morning | Evening |
| 1 | 110 m | 120 m | 150 m | 180 m |
| 2 | 130 m | 105 m | 130 m | 110 m |
| 3 | 110 m | 145 m | 125 m | 140 m |
| | 80 s | 90 s | 100 s | 180 s |
| 4 | 140 m | 115 m | 160 m | 180 m |
| | 80 s | 120 s | 150 s | 170 s |
| 5 | 160 m | 130 m | 120 m | 165 m |
| | 130 s | 130 s | 150 s | 170 s |
| | 90 s | 85 s | 130 s | 170 s |
| 6 | 140 m | 140 m | 160 m | 150 m |
| | 140 s | 155 s | 115 s | 180 s |
| | 130 s | 160 s | 135 s | 120 s |

m denotes main stem leaf

s denotes sympodial leaf

In cultivars of rice, wheat and maize the angle of leaves is reported to affect growth, photosynthetic rate and grain yield (17, 23, 27). The leaves favorably inclined intercept more light and are supposed to photosynthesize more efficiently than the self-shading leaves. A number of reports in this regard are on graminacious plants with little information on dicot plants (28). It will be seen that from 1st to 5th node the lamina in the leaves of C 1412 comes nearly in line with the peticle. These movements enable the plant to expose most of the leaf surface to sunlight. The leaves of C 1412 continued to turn towards the direction of the sun even during cloudy weather throughout the day without sunshine.

### Drought tolerance: leaf anatomy and root system

At or above the 10th main stem node, leaves of Asiatic cottons (*G. arboreum* and *G. herbaceum*) are known to have both an upper and a lower palisade layer with a reduced spongy parenchyma in between (24). The decreased cell size, a higher stomatal frequency and palisade developed at the expense of spongy mesophyll are considered as some of the important characters for leaf xeromorphy as related to water stress (25). The cotton cultivars belonging to *G. hirsutum* and *G. barbadense* also vary considerably in their foliar anatomy (12).

The drought tolerance generally observed in Asiatic cottons appears largely due to more of total palisade thickness. In this context the differences between the thickness of palisade and spongy parenchyma are considerably higher in Okra and C 1412 than in MCU 5, MCU 7 and B 1007 (Table 9). Both MCU 5 and MCU 7 are grown under irrigated conditions and B 1007 under assured rainfall conditions. Therefore thicker leaves alone or only the thickness of palisade alone may not be the true criteria for determining tolerance to drought. Instead, relatively thicker palisade in *G. hirsutum* cottons with thinner epidermal layers would be better indicators for drought tolerance. C 1412 has been found to grow successfully under conditions of low rainfall. Its palisade layer is similar to the adaxial palisade of K 7 as are also the upper and lower epidermal layers.

The length of tap root in rain grown plants of K 7 (*G. arboreum*) and three *G. hirsutum* cultivars were traced at maturity (Table 10). It will be seen that the main root of C 1412 reached the same depth as K 7 and that of PRS 72 was still deeper. These genotypes had more or less the same number of lateral roots. The compact types PRS 72 and C 1412 could extract moisture from the same depth as the Asiatic type K 7 known for its tolerance to drought.

Table 9. Tissue thickness in microns.

| Species | Cultivar | Upper epidermis | Adaxial palisole | Spongy parenchyma | Adaxial palisade | Lower epidermis |
|---|---|---|---|---|---|---|
| *G arboreum* | K 7 | 21.3 | 162.7 | 112.0 | 50.6 | 10.6 |
| *G. hirsutum* | MCU 5 | 26.6 | 136.0 | 122.7 | – | 16.0 |
| – do – | MCU 7 | 29.3 | 189.3 | 176.0 | – | 24.0 |
| – do – | B 1007 | 24.0 | 141.3 | 130.7 | – | 28.6 |
| – do – | Okra | 21.3 | 149.3 | 122.7 | – | 21.3 |
| – do – | C 1412 | 21.3 | 160.5 | 138.6 | – | 10.6 |

Table 10. Root length and number in a few cultivars.

| | K 7 | Okra | PRS 72 | C 1412 |
|---|---|---|---|---|
| Length of top root | 65.0 | 59.7 | 73.7 | 67.0 |
| Lateral roots | 10.0 | 9.3 | 9.0 | 13.1 |

### Nutriment uptake and utilization

Though nutriment uptake by the cotton plant at different stages of growth has been studied by different workers (14, 22), Bhatt and Appukuttan (9) showed that the uptake is governed by plant architecture. It has been shown in the beginning how the compact type PRS 72 and the traditional type MCU 1 have different morphological frames as also dry matter per plant.

The long duration cultivar MCU 1 continued to be more vegetative for about the first 100 days after sowing and most of nitrogen, potash and phosphorus absorbed were utilized for vegetative growth. During bolling phase only its vegetative parts showed a rapid decline in nutrient contents (Table 11). On the contrary, distribution of nutriment appeared to be balanced in PRS 72 because of its less vegetative habit and the tendency to fruit early. From bud initiation to bolling, differences in nutriment contents of vegetative as well as fruiting parts were much narrower in PRS 72. After flowering, phosphorus contents of fruiting parts remained higher than that of leaves and stem unlike the pattern observed in MCU 1. Perhaps a better energy turnover through phosphorus metabolism for reproductive growth is indicated in PRS 72. At crop maturity nutrients in leaves and stem of PRS 72 were reduced appreciably whereas more quantities remained unutilized in MCU 1.

It will be seen from Table 12 that to produce the same quantity of yield PRS 72 required less quantities of nutriments. A compact type, besides better yield capacity, has the additional advantage of economic utilization of fertilizers. Bhatt *et al* (10) have also shown that the progeny where compactness as character has been transferred, offers the same benefit as the parent plant.

### Conclusions

The plant type concept for rain grown cotton is dictated by the environment where cloudy weather, reduction in daily sunshine hours and uncertain rainfall act as limiting factors for growth and yield. From the foregoing discussion on useful characteristics involving several genotypes, the following points emerge.

A compact structure with open canopy to give adequate but not too high LAI for quicker growth, and amenable to closer spacing is preferable. An open canopy means better setting of bolls and their development besides more effective management of pests and diseases. Instead of the extreme short branch, the sympodia should be extended from 2-4 nodes with or without clustering habit. This envisages a dwarf to semi-dwarf stature reaching not more than a metre in height.

The leaves should be relatively smaller in size and although an open canopy facilitates more penetration of light, their turning towards the sun ensures relatively better photosynthetic efficiency during cloudy weather as hours of bright sunshine per day in rain

Table 11. Nutrient content per plant (g).

| Cultivar | Vegetative parts | | | Fruiting parts | | |
|---|---|---|---|---|---|---|
| | Flowering | Early boll bursting | Maturity | Flowering | Early boll bursting | Maturity |
| | | | Nitrogen | | | |
| MCU 1 | 1.15 | 3.81 | 1.80 | 0.05 | 0.49 | 1.82 |
| PRS 72 | 0.22 | 0.63 | 0.35 | 0.10 | 0.52 | 0.70 |
| | | | *Phosphorus* | | | |
| MCU 1 | 0.40 | 1.28 | 0.58 | 0.11 | 0.27 | 0.65 |
| PRS 72 | 0.07 | 0.25 | 0.08 | 0.03 | 0.33 | 0.23 |
| | | | Potash | | | |
| MCU 1 | 1.10 | 4.01 | 2.25 | 0.10 | 0.62 | 1.70 |
| PRS 72 | 0.21 | 0.68 | 0.50 | 0.08 | 0.45 | 0.60 |

Table 12. Yield of seed cotton and nutrients removed (as contained in the final stand of the crop) in kg/ha.

| Cultivar | Seed cotton | N | P | K |
|---|---|---|---|---|
| MCU 1 | 3 017 | 217 | 72 | 227 |
| PRS 72 | 3 151 | 130 | 44 | 136 |
| Difference | 133 | 87 | 28 | 91 |

grown cotton tracts decrease considerably during monsoon (on an average from 2.5 to 3 hours).

The sympodial leaf in cotton is known to translocate the assimilate to fruiting bodies on upper and lower sympodia, and the main stem leaf to lower sympodia alone. But the main stem leaves of short-branch cultivars have been shown to transport the assimilate to upper sympodia also because of the particular spatial arrangement of leaves and bolls (8).

A palisade layer thicker than spongy parenchyma (preferably one and a half times or more) and thinner epidermal cells would bring the proposed *G. hirsutum* ideotype nearer to the Asiatic type for tolerance to drought. Since water-requirement during boll growth is more than during vegetative phase, a deeper root system would enable the plant to extract moisture from lower soil-depths.

A compact plant body has been shown to produce adequate quantities of dry matter for balanced growth and higher yield by limiting vegetative over growth and reduction in excess dry matter with consequent increase in fruiting coefficient. Thus for every gram of dry matter produced more seed cotton can be expected because of proper partitioning of the photosynthate.

Since plant architectures determines nutrient uptake, the proposed reduction in plant size means better and economic utilization of absorbed nutrients and hence less of fertilizer application.

Apart from moisture stresses created by erratic rainfall, even in a normal year the cotton crop suffers from water logged conditions during early growth and moisture stress during the bolling period which adversely affects the yield of traditional long duration cultivars. Lack of rains even during the last 2 to 3 weeks of the monsoon is enough to lower the yield drastically. The plant type envisaged should therefore have the desired earliness to fit in the rainfall pattern and avoid moisture stress during the later phase of boll growth.

The belt covering large tracts of rain grown cotton in India between the latitudes 18°N and 24°N extends from the western coastal areas of the States of Gujarat and Maharashtra to Orissa and north-eastern parts of Andhra Pradesh. Most of the cotton produced is of medium staple and quality. The crop is sown during the last week of June or first week of July depending upon the onset of south-west monsoon. In a normal year rains are received till mid-September. In this belt at certain locations C 1412 was grown during 1979-80 season. No rains were received after mid-August. The local cultivars suffered from severe drought and their seed cotton yield ranged from 50 kg to 150 kg per hectare as against 200 kg to 400 kg of C 1412. Because of its earliness C 1412 could be harvested by the end of October and wherever supplemental well irrigation was available it gave over 20 quintals of seed cotton per hectare and a crop of wheat could also be sown in the first week of November.

Though C 1412 would appear to fulfill many of the criteria enumerated above, there is need to synthesize a plant type with a better blend of these characteristics for greater tolerance to environmental stresses and more productivity.

## Abstract

For rain grown cotton where environmental stresses like cloudy weather, reduction in daily hours of sunshine and uncertain rainfall limit growth and yield, an ideotype is suggested to stabilize production at higher levels.

A compact plant structure with open canopy, leaves relatively smaller in size well inclined to intercept maximum light and showing heliotropic movements, short multinoded sympodia and a deeper root system is considered efficient. A semi-dwarf stature reaching not more than a metre and amenable to closer spacing is proposed. The leaf anatomy with a very thick palisade than spongy parenchima and thinner epidermal layers is preferable for tolerance to drought. The plant should be of shorter duration and mature early so as to finish its life cycle within 120 to 130 days. The proposed plant type is expected to produce adequate quantities of dry matter for balanced growth, higher fruiting coefficient and utilize the absorbed nutrients economically.

## Literature cited

1. ASHLEY, D.A. $^{14}$C-Labelled photosynthate translocation and utilization in cotton plants. Crop Science 12:69-74. 1972.

2. ASHLEY, D.A., DOSS, B.D. and BENNETT, O.L. A method determining leaf area in cotton. Agronomy Journal 55:584-585. 1963.

3. BABA, I. Breeding of rice variety suitable for heavy manuring. Japanese Journal of Breeding, 4:167-184. 1954.

4. BABA, I. Mechanism of response to heavy manuring in rice varieties. International Rice Commission Newsletter, 10:9-16. 1961.

5. BHATT, J.G. Yield capacity of cotton plant in relation to the production of dry matter. Indian Journal of Plant Physiology, 13:219-224. 1970.

6. BHATT, J.G. Leaf growth and leaf area index in morphologically contrasting varieties of cotton. Cotton Growing Review 51:187-191. 1974.

7. BHATT, J.G. Differential response of cotton to cycocel plant growth regulant. Turrialba 25:325-326. 1975.

8. BHATT, J.G. Translocation of labelled assimilate in morphologically contrasting cotton plants. New Phytologist 76:53-57. 1976.

9. BHATT, J.G. and APPUKUTTAN, E. Nutrient uptake in cotton in relation to plant architecture. Plant and Soil 35:381-388. 1971.

10. BHATT, J.G., RAMANUJAM, T. and APPUKUTTAN, E. Growth and nutrient uptake in a short branch strain of cotton in relation to its parents. Cotton Growing Review 51:130-137. 1974.

11. BHATT, J.G., SHAH, R.C. and SHARMA, A.N. Net assimilation rate of cotton in relation to spacing. Journal of Agricultural Science, Camb., 86:281-281. 1976.

12. BHATT, J.G. and ANDAL, R. Variation in foliar anatomy of cotton. Proceedings of the Indian Academy of Sciences, 88:451-453. 1979.

13. CROWTHER, F. Studies of growth analysis of the cotton plant under irrigation in Sudan. III. A comparison of plant development in Sudan Gezira and Egypt. Annals of Botany (N.S.) 8:213-257. 1944.

14. DASTUR, R.H. Physiology of the cotton plant in India. (Published by the Indian Central Cotton Committee, Bombay). 1960.

15. DASTUR, R.H. and AHAD, A. Studies in periodic partial failures of the Punjab-American

cotton in the Punjab. XIV. Mineral metabolism of normal and tirak affected plants. Indian Journal of Agricultural Sciences 15:63-74. 1945.

16. DONALD, C.M. The breeding of crop ideotypes. Euphytica 17:385-403. 1968.

17. EASTIN, J.D., HASKINE, F.A., SULLIVAN, C.Y. and VAN BANAL, C.M.H. Physiological aspects of crop yield. Madison, U.S.A. American Society of Agronomy, pp. 50-51. 1960.

18. ENGLEDOW, F.L. and WADHAM, S.M. Investigations on yield in the cereals. Journal of Agricultural Science Camb., 13:390-439.

19. HOPKINSON, J.M. Studies on the expansion of the leaf surface. IV. The carbon and phosphorus economy of a leaf. Journal of Experimental Botany 15:125-137. 1964.

20. JENNINGS, P.R. Plant type as a rice breeding objective. Crop Science 4:13-15. 1964.

21. MURATA, Y. Studies on the photosynthesis of rice plants and its culture significance. Bulletin of National Institute of Agricultural Science, Japan. Series D9, 1-169. 1961.

22. OLSON, L.C. and BLEDSOE, R.P. The chemical composition of the cotton plant and the uptake of nutrients at different growth stages. Georgia Agricultural Experimental Station Bulletin No. 222. 1942.

23. PENDLETON, J.W., SMITH, G.E. WINTER, S.R. and JOHNSTON, T.J. Field investigations of the relationship of leaf angle in corn (*Zea mays* L.) to grain yield and apparent photosynthesis. Agronomy Journal 60:422-424. 1968.

24. SAINI, A.D. and GADKARI, P.D. Some preliminary observations on the foliar anatomy of Indian Cottons. Indian Cotton Growing Review 14:89-95. 1960.

25. SHIELDS, L.M. Leaf xeromorphy as related to physiological and structural influences. Botanical Review 16:399-447. 1950.

26. SWAMINATHAN, M.S. Agricultural Research – Progress, Problems and Prospects. Journal of Bombay Natural History Society 67:466-480. 1970.

27. TANAKA, T. and MATSUSHIMA, S. Analysis of yield determining process and its application to yield prediction and culture improvement of low land rice. 103. On factors affecting the light curves of carbon assimilation in rice plant communities. Proceedings of Crop Science Society Japan. 40:376-380. 1971.

28. TRENBATH, B.R. and ANGUS, J.F. Leaf inclination and crop production. Field Crop Abstracts 28:231-244. 1975.

29. TSUNODA, S. A developmental analysis of yielding ability in varieties of field crops. II. The assimilation system of plants as affected by the form, direction and arrangement of single leaves. Japanese Journal of Breeding 9:237-244. 1959.

30. WATSON, D.N. The dependence of net assimilation rate on leaf area index. Annals of Botany (N.S.) 22:37-54. 1958.