# Light and Simplified Cultivation (LSC) Techniques and Their Relevance for Africa

**Hezhong Dong,** Cotton Research Centre, Shandong Academy of Agricultural Science, Jinan 250100, Shandong, P. R. China. E-mail address: donghz@saas.ac.cn; and

**Michel Fok**, CIRAD, UPR AIDA, F-34398 Montpellier, France

## Abstract

During the last two decades of 20th century, the application of intensive cultivation technologies has helped China to enhance yields and emerge as the world's largest cotton producer. But this approach is being debated now because of the increasing labour costs, that are linked to the rapid ECONOMIC development and urbanisation of the country. A new approach called 'light and simplified cultivation' (LSC) has been initiated to respond to the new context. This approach become more relevant to the small-scale farming systems of China as opposed to the complete mechanisation observed in developed countries. The approach of light and simplified cultivation (LSC) aims to reduce labour intensiveness. It simplifies cultivation management, diminishes the frequency of field operations, and adjusts techniques that blend with their implementation by machines. Promising techniques have been already obtained, such as single-seed precision sowing, control of vegetative branches without pruning, one-time fertilisation, fertigation, and maturity grouping for unique harvest. LSC technology is believed to provide a solid support for sustainable production of cotton in China and holds tremendous promise for yield-enhancement in the small-scale farming systems in Africa.

**Keywords:** cotton; light and simplified cultivation; cost-saving

## Introduction

Cotton has been of vital importance to the Chinese economy. It is the main agricultural product associated with the textile industry that has contributed substantially to the economic development since the early 1980s and in which China has ranked first for three decades.

China's achievements in cotton production have resulted from the application of intensive farming technologies, in terms of input use and of labour investment (Dai and Dong, 2015). The intensive farming technologies are highly labour-intensive. Labour is required to implement seedling thinning, plant pruning to eliminate vegetative branches and growth terminals of main-stems, split fertilisation and multiple-pickings (Dai and Dong, 2014).

The continuation of these labour intensive practices for productive and profitable cotton cropping is at stake because of several socio-economic factors. The rising urbanisation has decreased the availability of rural labour workforce, due to which, wages of rural labour have greatly increased. Increased labour costs hinder the application of some labour-intensive techniques. The availability of family labour has also been reduced due to farmers' aging, and the additional burden of the elderly having to look after the offspring of their children who have migrated for city jobs (Wang et Fok, 2017). The increased costs of agricultural inputs such as quality seeds and fertilisers exacerbated the crisis.

Chinese scientists have responded to the new socio-economic challenges by developing new simpler technologies that could reduce drudgery. Their approach to adjust the techniques of intensive cropping, is called Light and Simplified Cultivation (LSC) (Dai *et al.,* 2017).

The LSC techniques have been developed to reduce drudgery and simplify canopy management for high yields, which may suit the small-scale farming conditions of African countries.

## Concept and Characteristics of Light and Simplified Cotton Cultivation

The approach of LSC is based on two dimensions of adaptation to reduce or replace manual operations (Dong *et al.,* 2016; Dai *et al.,* 2017). The first dimension is to focus on new techniques to simplify cultivation practices, reduce the frequency of field operations, and adjust the implementation of techniques in view of their mechanisation. The second dimension takes the variation of local farming characteristics into account. It is pertinent to mention that the local farming practices can differ a lot, not only between the Northwestern region and the valleys of Yellow and Yangtze rivers, but also between different locations within the same valley.

The meaning of LSC in cotton cropping needs elaboration. "Light" refers to the small-scale agricultural machinery, materials, and equipment designed to reduce or replace manual operations. "Simplified" deals with the implementation of field operations whose frequency is reduced and which are less inter-linked, so that the overall management of cultivation is made easier. Hence, "Light and simplified" pertains to a systemic connotation through the integration of small-scale agricultural machinery and agronomic practices, and of new techniques with inputs of quality seeds or fertilisers. Although illustrative examples are few, the LSC approach considers the combination of fibre quality with quantity, as well as the concern for ecology and environment (Dong *et al.,* 2016; Dai *et al.,* 2017).

In cotton cropping, several characteristics of LSC are worth emphasising. First, LSC is not relevant only in a specific period or for a specific operation, it applies over the whole cropping cycle. Second, the modalities of its implementation could vary according to periods, regions and notably farming characteristics (Dong *et al.,* 2016). Finally, LSC is inherently dynamic and evolving. Techniques, management methods, machine types, and other necessary measures could be continuously upgraded, improved and made more adapted to local conditions. Thus, LSC implies moving forward with constant upgradation.

LSC in cotton cropping complies with the objectives of productivity and mechanisation under variable farming characteristics. The intensive cultivation techniques are not discarded but are adjusted to make them compatible with the new farming challenges. The objective of 'productivity-enhancement' is constrained by the large population and limited arable land. Though the basic principles and methods that have worked for the last three decades are still valid, the former techniques need contextual adaptation. For example, the use of film-mulching or the operation of plant pruning to remove unproductive vegetative branches still make sense, but the implementation practices differ.

## Key Technologies of LSC in Cotton Cropping

### Precision mono-seeding technology

Cluster seeding (up to 10 seeds per hill) used to be a popular technique for cotton production in China. The seeding rate of cotton was usually 35 to 45 kg per hectare, and the resulting number of seedlings was always much larger than the targeted plant density. The cluster seed method required one or two times of manual thinning to remove the extra seedlings after emergence (Dai and Dong, 2015). Such a technique is difficult to follow now due to labour scarcity, high labour wages and increased cost of seeds.

A new technique called 'Precision mono-seeding' is based on using high-quality seeds sown as single-seed per hill on finely prepared soil-beds, at row spacing defined for mechanical sowing (Kong *et al.,* 2018). This technique is applied through diverse modalities depending on regions.

The mono-seeding technique has been established and was applied first in the mono-culture cotton area of the Yellow River valley, wherein, sowing is done before spreading the mulching film.

In the north-western region, the precision mono-seeding technique is implemented by a machine which spreads the mulching film, punches holes, and drops down a single seed in each hole at the desired depth. This technique eliminates the need for seedling thinning and freeing seedlings from the underside of the plastic film.

Precision mono-seeding is applied also in areas where cotton is grown following a double cropping system and where cotton is transplanted. In the valleys of Yellow and the Yangtze rivers, cotton used to be relay-cropped with a winter crop such as garlic, wheat or rapeseed. The release of new varieties of shorter cycle, shorter by 30 days than the varieties commonly used, enables the establishment of a desired plant population by sowing a single seed, with machines thereby harvesting good yields before the onset of winter. The reduction of labour requirement with the 'precision mono-seeding' technique is particularly substantial (Lu *et al.,* 2017).

### Light and simplified seedling nursery technology

Raising seedlings and transplanting of cotton has been widely adopted since the 1980s, especially in the valleys of Yangtze and Yellow rivers (Dai and Dong, 2014). These techniques were used for many years, despite being labour intensive in preparing seedlings, raising them in nursery and in transplanting them in field. Seedlings were obtained by sowing in small column-shaped blocks of soil, which had to be prepared in a nursery constituted of a tunnel made with a plastic film stretched over arches of bamboo sticks. The preparation of soil blocks is labour intensive and physically harsh particularly to women.

The seedling nursery and transplanting technique has been made light and simplified while following the same principles. Seeds are sown in small plastic pots containing a commercial matrix (mixtures of peat, vermiculite, and river sand) instead of handmade soil blocks. The growth of seedlings is enhanced by the use of root growth promoter, leaf preservation agents and other plant growth regulators. More importantly, seedlings can be produced at industrial scale (Dong *et al.,* 2016) because the number of seedlings per unit area is increased significantly due to the shift from soil-blocks to small pots containing a specific substrate. The industrial production of seedlings is enhanced by the technique of bare-root seedlings growing on a very light sand-based substrate. Consequently, cotton producers do not have to produce seedlings by themselves; they can buy seedlings exactly like the way they do for seeds.

The transplanting technique is enhanced through the LSC approach due to the availability of machines that enable transplanting in a semi-mechanical or fully mechanical mode. In a semi-mechanical mode, the machine digs the holes and workers fill the holes manually with seedlings.

(a) (b) (c) (d) (e) (f) (g) (h)

Fig.1 Precision monoseeding and seedling transplanting. (a) precision monoseeding by a machine which spreads the mulching film, punches holes, and let down a single seed in each at the desired depth in monoculture; (b) a cotton field from mono-seeding at seedling stage; (c) traditional seedling raising with soil blocks; (d) and (e) Seeds are sown in sand or on small plastic pots containing a commercial matrix to raise seedlings; (f) mechanic transplanting; (g, h) directly seeded short-season cotton after garlic or wheat.

In the fully mechanical transplanting mode, labour is used to feed the machine with seedlings.

## Non-pruning technology

Plant pruning is also a widely adopted intensive cultivation technique in China; it involves the removal of vegetative branches and the apical bud (plant topping) at distinct times. Plant pruning is implemented because it can optimally coordinate vegetative and reproductive growths by adjusting the distribution of nutrients in cotton plant tissues, thereby reducing the nutrient consumption by unproductive parts of the plant (Dai and Dong, 2016). In addition, plant pruning also improves the microclimate of the cotton field so that boll abscission and boll rot are reduced thereby enhancing yield and fibre quality (Dai and Dong, 2014; Dai *et al.,* 2014).

The need to remove vegetative branches is eliminated in the LSC approach simply by preventing the vegetative branches from developing. The development of vegetative branches can be greatly inhibited by increased plant population density as various studies have demonstrated. A non-pruning technology is now launched; it consists of setting up a large population of small individual plants whose growth is properly regulated. In the Yellow river valley, plant density has been increased to 90,000 plants/ha from the common density of 30-40,000 plants/ha. In the North-Western region, plant density has been increased to about 200,000 plants/ha (Feng *et al.,* 2017).

Growth of the apical bud is now restricted using chemical growth regulators instead of the manual de-topping methods that were used earlier. In the North-western region where production is fully irrigated, mepiquat chloride is applied with irrigation to inhibit the growth of the apical bud. In the Yellow River valley, chemical topping is achieved by adjusting the growth regulation program by increasing the number of applications and augmenting the dosage of the last application substantially.

## One-time fertilisation technique

Under the earlier techniques of intensive cultivation, cotton used to be grown with relatively large amounts of up to 225-270 kg/ha of nutrients of conventional fast-release chemical fertilisers, in the Yellow and Yangtze River valleys and 300-330 kg/ha in the Northwestern region (Dai and Dong, 2014). The LSC approach has led to a reduction in the number of fertiliser applications and the amounts of fertilisers under various conditions depending on regions and yield targets.

- In the Yangtze River valley, seed cotton yield is expected at 3,600–4,500 kg/ha for N application of 225 kg/ha. Nitrogen, Phosphorous and potassium are applied following the ratio of 1.0-0.6-0.8 for N-$P_2O_5$-$K_2O$.
- In the Yellow River valley, application of N at 195 kg/ha results in seed cotton yield at 3,000–3,750 kg/ha. When expected yields are higher than 3,750 kg/ha, the amount of N is increased to 210 kg/ha, and phosphorous and potassium are applied following the ratio of 1.0-0.6- 0.8.
- In the North-western region, the yield of seed cotton could reach 4,500–5,250 kg/ha and the required amount of N is 280 kg/ha. The ratio of N-$P_2O_5$- $K_2O$ is approximately 1.0-0.5-0.2. The amount of fertilisers can be reduced by approximately 15% when fertigation is implemented (Lin *et al.,* 2013; Dai *et al.,* 2017b).

The adoption of special slow-release fertilisers can help to reduce the frequency of fertiliser application. In Yangtze River valley as well as in Yellow River valley, a single basal application of controlled or slow-release fertiliser is ade-

(a) (b)

Fig. 2 In crop tillage: traditional way (a) and current mechanic way (b)

(a) (b)

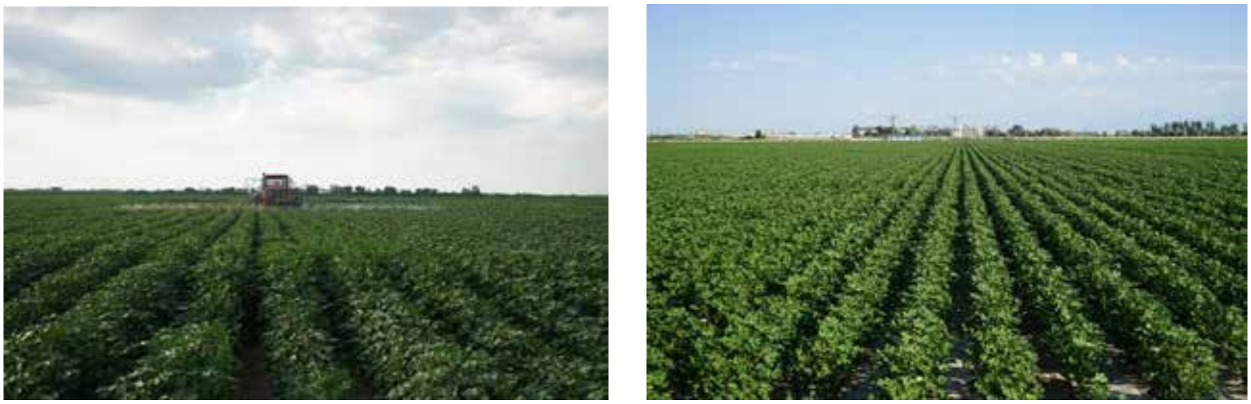

Fig. 3 Non-pruning cotton field under high plant density and chemical topping

(a) (b)

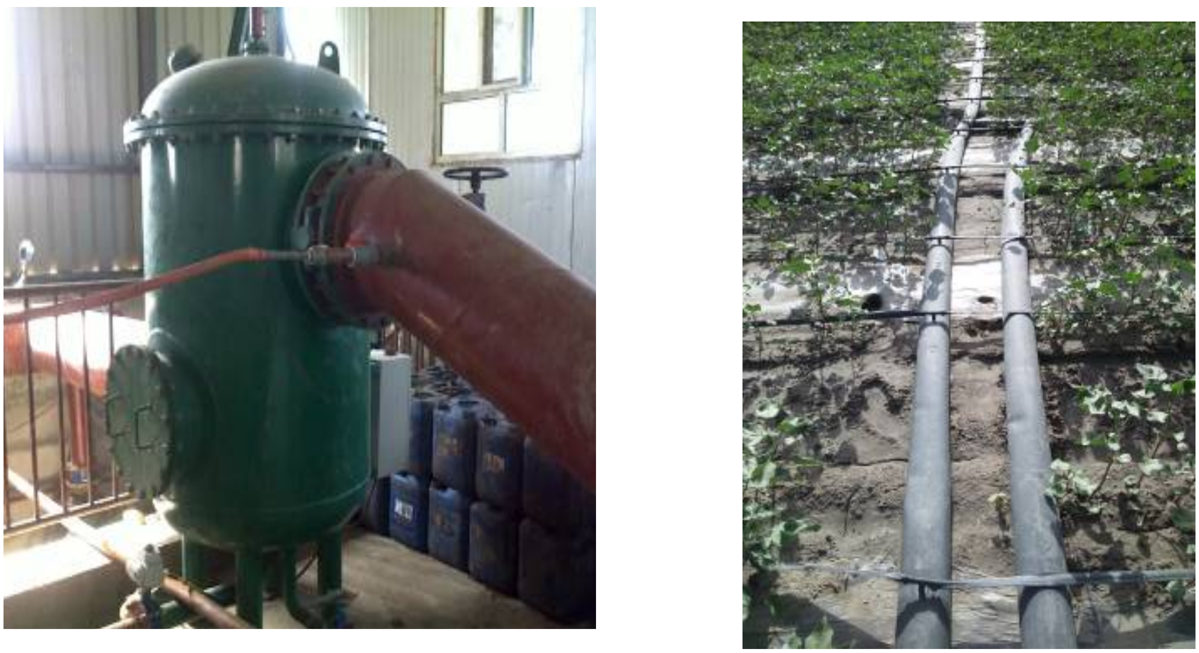

Fig. 4 Fertigation in drip irrigation under plastic mulching: (a) tank containing fertiliser for fertigation; (b) drip irrigation belt

quate for the season. In addition, the quantity is reduced by 10% compared to using standard fertilisers (Geng *et al.,* 2016).

## Fertigation technology

The efficiency of water-use in irrigation is improved when effective technology of water-saving is applied. The extent of the improvement achieved varies depending on regions.

In the fully irrigated cotton production systems in the north-western region, drip irrigation under the plastic mulching is most commonly deployed. It is implemented through a low-pressure pipeline system for water supply; pressurised water is filtered and injected with the water-soluble fertiliser. The aqueous fertiliser solution uniformly infiltrates by drip in area concentration around the root to maintain the desired moisture level as prescribed for water and fertiliser. On an average, water consumption is reduced by 12% compared to traditional furrow irrigation and by 50% compared to sprinkler irrigation. The amount of fertiliser required is also reduced by 15 to 20% (Luo *et al.,* 2018).

In the Yellow River valley where irrigation is only provided before land preparation, the water use efficiency can be greatly improved by border or furrow irrigation as compared to flood irrigation. The shift from long plots to short plots, from wide plots to narrow ones, and from large to small plots have increased water use efficiency. The reduction of the amount of water used in irrigation operations has led to conservation of irrigation water.


Fig. 5 Technology for holistic control of plant population in Yellow River (a, b) and North-west inland (c, d)

## Technology for plant population management

In China, synchronous boll bursting can lead to one or two pickings as compared to the current systems of multiple pickings. In the intensive cotton production system, cotton is picked 4-5 times, which is time-consuming, labour-intensive and less acceptable due to scarce availability of labour.

The impact of regulating and optimising cotton plant population in realising higher yields is very significant. It is an effective way to improve the micro-ecological environment of a cotton field and to coordinate the nutrient distribution between roots and shoot and photosynthate partitioning between sink and source. Optimum plant population and canopy management also improve the light use efficiency, to increase the yield and fibre quality, and to achieve a synchronous boll opening for easier harvest.

The techniques to achieve desired plant population structures are different in different cotton growing areas. These techniques are generally adapted to local conditions.

In the North-western region, five factors are managed to reach the desired population structure for mechanical harvest:

- The first factor is the selection of suitable cotton varieties combining the characteristics of early maturity, high yield, fibre quality, stress-resistance, and appropriate plant architecture.
- The second factor is the use of high-quality seeds to be sown in time and properly on finely prepared soil-beds. A sowing depth of about 2.5 cm ensures full and strong stand establishment under precision mono-seeding.
- The third factor is to adjust density with plant height. For mechanical harvesting, the plant height has to be relatively augmented by reducing the plant density commonly set up. In the northern part of Xinjiang, the number of harvested plants is adjusted to 180,000–210,000 plants/ha to obtain 70–80 cm height. In the southern part of Xinjiang area, plant population is reduced to 150,000–195,000 plants/ha to achieve a plant height of 75–85 cm.
- The fourth factor pertains to the management of plant canopy and nutrition in irrigation under plastic mulching. Water, fertiliser, and plant growth regulators are fine-tuned to regulate the canopy and nurture the root system of cotton plants.
- The fifth factor is to maximise the photosynthetic ca-

pacity of the non-leaf green organs. This capacity can be increased through the breeding of cotton varieties with sturdy stems and large bracts. The expression of this capacity is controlled by a reasonably high planting density, proper row spacing, and appropriate provision of water and fertiliser.

In the Yellow River and Yangtze River valleys, the desired plant population structure is achieved by controlling various factors.

- Crop density is increased, and plant height is reduced. In Yangtze River valley where hybrids are also grown, the density is increased from 15,000–18,000 to 22,500–37,500 plants/ha. In Yellow River valley, plant density is increased by 20,000–30,000 to reach about 90,000 plants/ha but with reduced plant height to 90-100 cm so as to ensure timely and appropriate canopy closure.
- Traditional wide and narrow row spacing is replaced by equal row spacing suitable for mechanical harvesting. The row scheme of single rows every 76 cm is being retained. It differs substantially from the scheme alternating double narrow lines (50-60 cm) separated by large inter-row of 90-120 cm. Plant growth regulation is adjusted in a timely manner to ensure desired row closure.
- The plant population structure is managed along the promoted development of the root system. Such a development is achieved by deep ploughing (up to 30 cm) or deep loosening of the soil for every 2-3 years, with incorporation of crushed straws into the soil. The root system is also developed by the early underground application of controlled-release fertiliser, at 10 cm below the surface of the soil. It is also favoured by the timely removal or breakage of the plastic film, at full squaring stage, associated with tillage.
- Full maturity of bolls is obtained through delayed senescence. It is achieved by using suitable cotton varieties with desired plant shape and size. The period of cotton boll opening can be compressed from more than 70 days to 40 days, hence enabling grouped harvesting and more suitable for mechanical picking.

In summary, the development and application of LSC are indispensable for the sustainable cotton production in China to comply with the scarcity and higher cost of labour. For the techniques already operational, the shift from the intensive cultivation system to LSC are significant.

In spite of the achievements presented above, there is a need for the development of new machines and equipment that are suited for the new LSC techniques in small-scale farming systems. The need for new machinery extends from sowing adaptation in the double cropping systems, fixed row spacing in ridges and furrows to mechanised harvesting.

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**The following table summarises the changes in the shift from the intensive system to LSC.**

| Operations | Intensive System | LSC System |
|---|---|---|
| Seeding and thinning | Conventional seeding, 30-45 kg seed per hectare, and 2-3 times of manual thinning | Precision seeding, 15-20 kg seed per hectare, no-thinning. |
| In-crop tillage | 5-6 times during the whole growth season. | 2 times at the full post emergence and full squaring or flowering stage. |
| Fertiliser application | 3-4 times with conventional fertilisers of rapid release, at planting, squaring or flowering stage and after topping. High labour input and low fertiliser use efficiency | Single time at planting with slow- or controlled-release fertiliser. Labour saving and high fertiliser use efficiency |
| Plant pruning | Manual removal of vegetative branches, old leaves and redundant buds as well as apical bud of the main stem. | Pruning is avoided due to increased plant density and application of plant growth regulators |
| Plastic mulching | Film thickness of 0.004-0.006 mm, no recycling of film is possible | Film thickness ≥0.01mm, film removal is easier and recycling is possible |
| Planting pattern | Relay intercropping through transplanting before harvest of winter crop | Direct seeding of short-season cotton after the harvest of winter crop |
| Cotton picking | Multiple manual pickings adapted to scattered distribution of bolls | One or two pickings of synchronous maturing bolls |
| Mechanisation | 40% covering land preparation, straw incorporation, sowing, fertiliser application and in-crop tillage | ≥90%, covering land preparation, straw incorporation, sowing, fertiliser application, in-crop tillage and harvesting |