

labour can be achieved without sacrificing the production levels of the block.

b) Replanting a Block/New plantation:

Whenever there is an opportunity to completely replant a block or to bring a new land under coffee cultivation, efforts have to be made to modify the terrain of the land and or planting designs to suit the movement of small tractors or rubberized track carriers. In certain cases, the number of plants per unit area may slightly decrease compared to traditional planting. The modifications to the terrain and planting designs would primarily depend on the slope of the land.

The suggested methods of land modifications and planting designs for different field situations to enable mechanization

Flat land to gentle slopes: Flat lands and gentle sloping lands do not require any land modification or land shaping. In such areas, adopting hedge row method of planting across the slope would be highly desirable. The most commonly adopted spacing for hedge-rows is 2m x 1m (6ft X 3ft) for Arabica coffee or alternatively wider hedge row like 10ft x 4ft / 12ft x3ft. Because of closer spacing of plants within a row, stems of the plants are covered more and thus reduce the chances of white stem borer attack. When planted in hedge rows, it is advised to construct farm paths (about 3 m wide) between 4 and 6 hedge rows for facilitating movement of small tractors or walk behind type of Rubberized Track Carriers etc.

Moderate slopes: In gentle to moderate slopes, contour farming/bunding is recommended at suitable intervals for minimizing erosion of top soil. Contour farming is the technique of growing crops "on the level" across or perpendicular to a slope rather than up and down the slope. The rows running across the slope are designed to be as level as possible to facilitate planting operations on the contour. Contour farming is most effective on slopes above 10 percent. Contour farming is not well suited to rolling topography having a higher slope with maximum irregularity. The contour bunds fortified with earthen embankment can act as narrow farm path for facilitating movement of small tractors or walk behind type of Rubberized Track Carriers. These farm paths can be fortified by planting soil binding grasses like Vetiver, Paspalum etc., on the lower side. At the end of each farm path there should be a provision for connecting the farm paths, taking care that the slope of connecting path is not exceeding 15 percent. The area between two contour bunds can be planted with coffee either in hedge row design or paired row design of planting.

Steep slopes: In steep slopes, it is suggested to construct bench terraces across the slope to minimize soil erosion as well as to improve the working conditions within the plot. Bench terracing involves transforming of relatively steep to very steep slope land into a series of steps running across the slope separated by vertical risers or terraces. The vertical risers (bench terraces) act as platform to plant coffee. On bench terraces coffee can be planted either in hedge row or paired row- triangular design. In very steep slopes (25% and above) coffee can be cultivated by bench terracing or by contour planting but introducing any large-scale mechanization may not be possible because farm- paths required for movement of machinery have to be constructed at very close spacing. Development of new suitable farm path system depending on the slope and shade tree population, selection of right planting design for the easy and convenient movement of small machinery to improve easy access to each plant or planted rows is the important step for mechanization of

the farm operations which would improve the efficiency of the farm labourers and thereby mitigate the labour constraint. It also helps in implementation of farm operations in a timely manner and ultimately reduces the cost of cultivation substantially.



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PLANTING DESIGNS FOR MECHANIZATION IN INDIA



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In India, coffee is grown on slopes in the hilly tracts under shade trees. Majority of the farm work is carried out manually, since there are no suitable machineries. Nowadays, there is a severe shortage of skilled and experienced farm workers. Thus, there is a great need to develop mechanized farming system for coffee cultivation. Use of improved machinery and farm implements to carry out different cultural operations and to increase the productivity of land and labour is the need of the hour in many agricultural crops including coffee. The concept of mechanization is relatively new in Indian coffee cultivation and it still remains primarily as a labour-intensive crop.

For the effective maintenance of coffee plantations in India, the annual requirement of labour for undertaking regular cultural operations is about 456 man days per ha in case of Arabica, 266 man days per ha in case of rain-fed Robusta and 326 man days per ha in case of irrigated Robusta coffee. The cost of labour alone constitutes about 60 to 70 percent of the total cultivation costs in case of Arabica and about 55 to 65 percent in the case of Robusta coffee depending on whether irrigated or not.

In recent years, shortage of labourers in coffee plantations is acute due to migration of workers to urban areas in search of better living. Thus, there is an imperative need to introduce mechanization to the possible extent to carry out field operations for improving the efficiency and productivity of labour and to reduce the cost of production.

Development of mechanized coffee estates

The various tasks that have to be performed on a coffee estate at different stages are plenty in number like the identification of suitable site for planting, clearing the land by removal of bushes, line marking, planting temporary and permanent shade trees in suitable places, pitting and preparing for planting, planting coffee seedlings etc. Use of machineries with various power sources and improved farm tools and equipments for timely completion of the various farm operations implies mechanization in coffee farms. To ensure efficient use of farm machinery, certain modifications are needed in the existing coffee planting designs.

Relevance of development of path ways in Indian Coffee Estates

Creation of farm paths and water conservation is very relevant to Indian coffee plantations for taking up mechanization activities as the coffee fields are located on gentle to very steep slopes and under the canopy of shade trees. The new farm path system technology with certain modifications can be extended to the Indian coffee plantations where preservation of permanent shade trees is as important as introducing mechanization in plantations. The first and foremost step involved in introducing mechanization of farm operations on a coffee estate is *creating farm paths for movement of small machines*. The farm paths have to be created through proper land shaping/scaping and based on the slope of the land, contour or terrace farming can be practiced without much damage to the shade trees. The working path is for moving small machines with crawler treads rather than wheels having a very small turning circle and the operator not riding

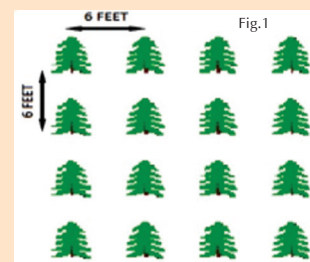
the machine but walking behind the machine. The connecting road interconnects all the working rows thus making it easy to take up continuous farm operations. Once land terrain is made amenable for movement of small machinery like Mini Tractors or Rubberized Track carriers, a suitable planting design which provides adequate space for the movement of machinery in between the rows should be chosen.

Generally adopted planting designs in India

Three types of planting designs are generally practiced in Indian coffee plantations, viz., square, hedge row and paired row planting.

Square system:

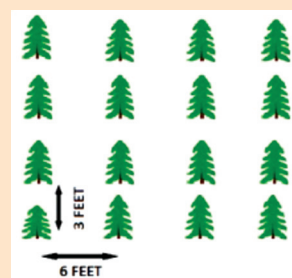
Generally square system of planting is found to be ideal for flat to gentle slopes. The distance between the rows and spacing of plants would depend upon the type of planting material. In general, the recommended optimum spacings for planting tall Arabica varieties (Sln. 5, Sln. 9, Sln. 795) are 6 x 6 feet or 7 x 6 feet or 7 x 7 feet while that for dwarf Arabica varieties is 5 x 5 feet. The ideal spacing recommended for planting the Robusta variety CXR is 8 x 8 feet and for the other two varieties, viz., S.274 and Old Robusta is 10 x 10 feet and 12 x 12 feet respectively. The square planting design is shown in Fig.1



The square planting design accommodates 1742 plants at 5 ft X 5 ft spacing and 1210 plants at 6 ft X 6 ft spacing per acre. Once the plants are established in the field the space between the rows are well covered reducing the accessibility to each plant. Hence this planting design is not a very ideal one for mechanizing the farm operations especially for free movement of the machine.

Hedge row system:

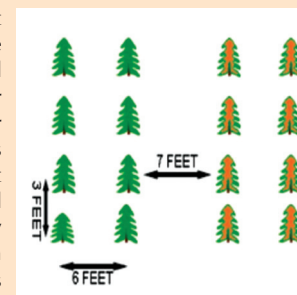
In hedge row method, the spacing within the row is less than the spacing between the rows, thus making a provision for wider working space between the rows. In Latin American and African countries, for Arabica coffee, 7 x 3 feet is the most commonly adopted spacing for hedge-rows. The hedge row planting is shown in Fig. In this planting design a plant population of 2420 can be accommodated in one acre area and it is more amenable for mechanization of farm operations as each plant can be reached easily. The high density of plants in a unit area helps in assured higher production levels.



Paired row system:

Paired row system of planting is also practiced in coffee. In this planting design, two rows are brought together followed by a wide gap before the next set of two rows. The spacing between inter rows is 6 feet and between intra rows 3 feet, with 7 feet spacing between next set of two rows. The advantages of this

kind of planting design is that wide spacing is available between any two sets of paired rows which can be utilized for movement of small tractors or rubberized track carriers. This system also permits better light interception by the plant and thus can give higher yields. By adopting this planting design about 2234 number of plants can be grown on one acre.



Planting designs based on condition and slope of land for mechanization

a) In Existing Plantations:

The present system of coffee cultivation on undulating terrain under the shade trees at irregular intervals coupled with square system of planting is not ideally suited for introduction of many types of machinery that can be driven / moved in between the coffee rows. Only small, handheld type of machinery like weed/brush cutters, pit diggers, handheld battery-operated harvesters can be used under the existing conditions.



It has to be noted that, majority of existing planting design is square planting in India. The hedge row and paired row systems are recently introduced in the plantations. If the existing blocks are to be made amenable for mechanization, it is necessary to create working space, narrow farm paths in between the existing planted rows. These working spaces or farm paths should be of about 1.5-meter width and formed along the contour lines. While forming the working space, removal of coffee bushes which fall in the area marked for creation of farm path may be required. Shade trees which are in the way of working row need not be removed, if possible, the farm paths can be laid around the shade trees.

The farm paths should be connected with each other at the end of the plot, so as to facilitate turning of small machinery from one working row to another. Once this is done, the Mini Tractors or Rubberized Track carriers can be used for operations like spraying and transportation of inputs or harvested fruits. These newly created farm paths help in improving the accessibility to every plant in the block and in turn the efficiency of all the field operations. Thus, a substantial savings in the farm inputs (like fertilizers, manures, plant protection materials etc.) and also

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