Vegetable Cultivation on Trellis *(Pandal)* Structures: Diverse Traditional Practices in India

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Vegetable Cultivation on Trellis (*Pandal*) Structures: Diverse Traditional Practices in India

(A visual documentation)

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Contents

1. Introduction and the need for the study

India is a vast country and diverse in many ways. People eat food prepared in different ways, speak a variety of languages, celebrate different festivals of their own, have local traditions, dress to suit their culture and local climatic conditions etc. Diversity is beautiful and a great strength. Freedom to be diverse cultivates innovations. We know that the same dish is prepared in quite different recipes and tastes in different places of India. Imagine if a rule is made that everyone in India shall eat food prepared in a particular way and with the same set of ingredients. How bizarre it sounds!

Agriculture in India has a history of several millennia with the earliest evidences traced back to the Indus Valley civilization sites, such as, Dholavira in Gujarat. Diversity is readily observed in many walks of life in India and the practice of agriculture is no exception. Many of the vegetable vines[1] are grown on trellises, locally called *pandals*, by Indian farmers (Fig.1)[2]. We find not only perennial and small vegetable such as pointed gourd, but also larger ones like ash gourd on

Fig.1: Different crops grown on trellises in India, (a) pointed gourd, (b) ridge gourd, (c) bottle gourd, (d) bitter gourd, (e) ash gourd, (f) broad beans, (g) snake gourd, (h) cucumber and (i) tomato

[1]Vines are the plants with a growth habit of trailing on stems

[2]The local name for 'trellis' in different locations is as diverse as the varieties of vegetable crops grown on them. Then, each such vegetable has more than a dozen local names due to different languages in different States in India. In this booklet, as a convention, English names of vegetables are used and a list of scientific names appended at the end of this report, sourcing from Tindall (1983) and Wikipedia contributors (2020, June 23).

trellis structures in backyards as well as in farmlands. Trellis is the practice of constructing a raised structure using poles of wood or other material so that climber varieties of vegetable crops spread and grow with good sunlight and aeration. Water and Livelihoods Foundation (WLF) stumbled upon various traditional trellis cultivation practices across India in recent years. Interestingly, they are quite diverse, low in cost and erected by small farmers in their own ways.

These traditional structures are quite different in their style of construction and use across India. On the contrary, there are some recent trellis promotion schemes by State and Central Governments that introduced 'standardization' in designs, use of raw materials and areal extent. The uptake of such schemes is not very extensive despite huge subsidies. These are out of reach of small farmers with tiny landholding, say 1 to 2 acres. These schemes also created an impression among many small farmers that trellis cultivation is not affordable and not meant for them.

On the other hand, it was observed that building the traditional trellis structures is quite easier and costs much less money. Most of these farmers, irrespective of their land holding, feel that cultivation of vegetables on trellises improves crop yield and quality, giving them better net incomes. Bellamkonda et al. (2020) quantified the production of ridge gourd crop on trellises in Nalgonda district, Telangana and showed 100% increase in the same compared to that as ground crop, with significant increase in net income to the farmers.

Therefore, this study report sets up three primary objectives:

1. To enlighten the readers on the diverse, ingenious and indigenous trellis cultivation practices in different parts of India
2. To dispel the myth that trellis cultivation is expensive and out of reach to small farmers
3. To encourage farmers and grass-roots organizations working with farmers to pick-up the best of these practices and 'innovate' their own methods and practices suitable to their areas

A field study done in association with several individuals and local NGOs gave deep insights into the traditional trellis practices across India. Around 85 villages in different districts of Gujarat, West Bengal, Tamil Nadu, Uttar Pradesh, Karnataka, Odisha, Jharkhand, Bihar, Madhya Pradesh, Andhra Pradesh, Telangana and Meghalaya were covered by randomly choosing few farmers from each village. Fig.2 presents these field study locations in the form of a map. These locations are not precise but only indicative. The number next to the location marker is the reference to the local contributor (NGO or individual) who contributed to the study as well as the field study area. List of these local contributors and field study areas is appended at the end of this report.

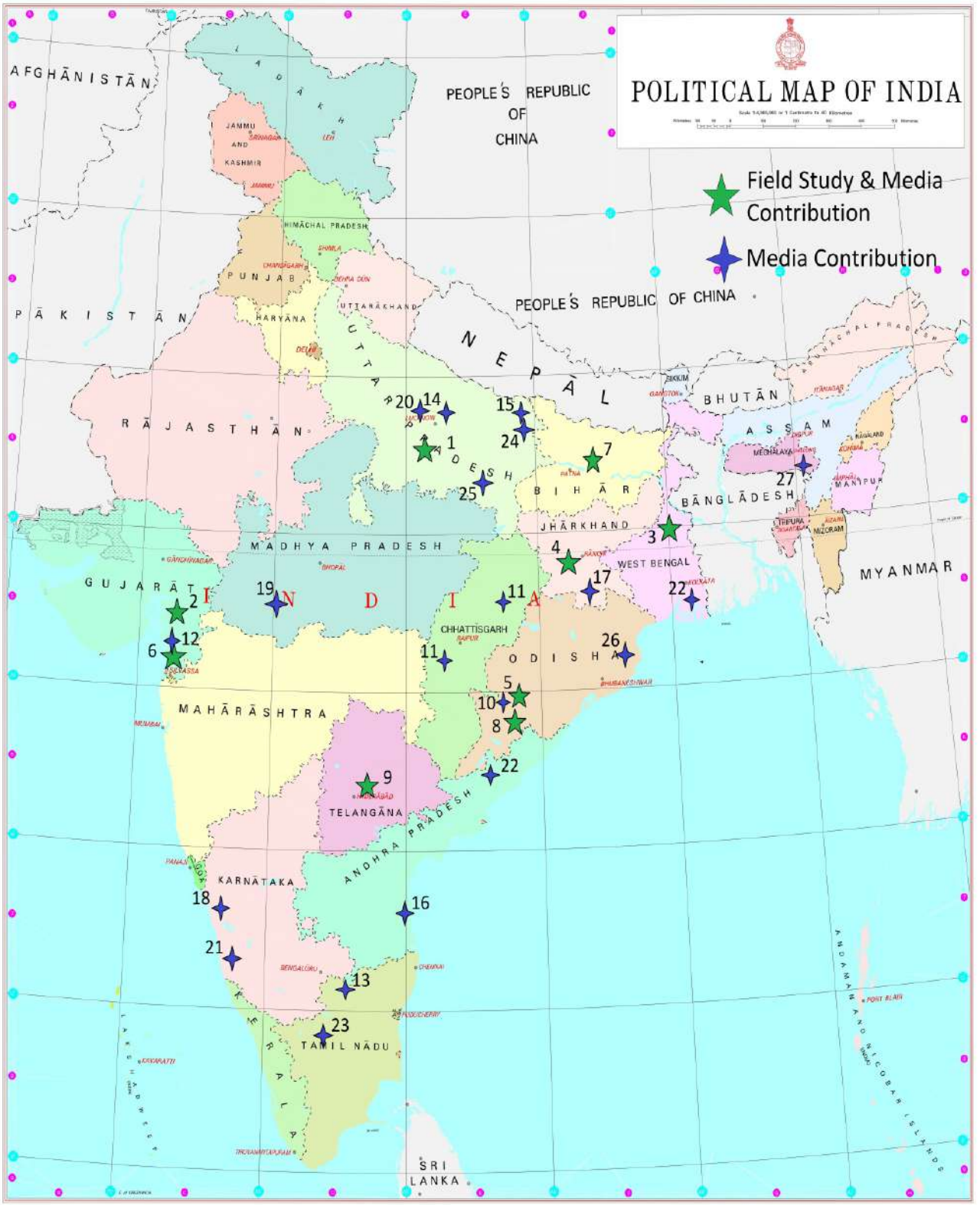


Fig.2: Field study locations (Map source: PIB 2019)

However, instead of presenting the study findings each location-wise, this report is organized around some unique features observed across locations. Categorization and presentation of these traditional trellis cultivation practices could as well be done in diverse ways. Here it is done based on the following parameters:

- *Size and location of the trellis structures*
- *Structural forms of construction*
- *Raw material used for constructing the trellis structures*
- *Cropping and agronomic practices*
- *Irrigation practices*
- *Tools and implements used by farmers*

Each of the above is presented as a separate chapter in the 'Findings and Discussion' section. These chapters form the core of this publication offering interesting insights to the readers. The 'Conclusion' section at the end briefly details the major outcomes of the study and draws their implications to the farming community at large.

2. Methodology

When this study was initiated in mid-March 2020, Covid-19 pandemic started showing its ugly face in several countries in the world. We did not expect it to spread to India at that time. Soon after, the lock-downs due to the pandemic imposed severe restrictions on the physical travels and visits by WLF team to different locations in India. Every crisis offers some opportunities as well. WLF took to the 'crowdsourcing' approach to carry out the study at different locations by involving several individuals and local NGOs. They were identified through open invitation for Expression of Interest (EoI). Each of them submitted few good quality pictures of local and traditional trellis practices in their areas. Interest to participate, inclination to do field studies and uniqueness of the trellis practices in their area were considered in selection of some of them. Other EoIs that contributed good information and pictures were also considered for synthesizing the analysis presented in this report.

In addition to the crowd contributions, the WLF team visited few sites where traditional trellis practices exist. Visits were also made to some farms where modern trellis structures were constructed, using stone and cement concrete pillars, on larger extents of land. Thus, by December 2020, we could prepare the draft of this report despite the Covid-19 pandemic-induced chaos in our personal and professional lives.

While compiling the information gathered from different locations, visual presentation of information is given priority than narrating in text form. The textual interpretations are intentionally made simple, jargon-free and to-the-point. Each of the pictures that are included in this booklet convey a specific and unique aspect of trellis cultivation. We believe that this approach of 'visual documentation' makes effective and lasting impression on readers than writing in textual and data-oriented form. Lastly, no attempt was made to analyse the trellis

construction costs or compare one with the other, at different locations across India. Farmers in remote tribal pockets sourced all the local materials at no cost. On the other extreme, some farmers purchase wooden poles and other materials from local markets. We thought that comparing costs is rather counter-intuitive to the spirit of appreciating diversity, which is the primary motive of this report.

3. Findings and Discussion

3.1. Size and location of the trellis structures

Trellis structures are found both in kitchen gardens and in farmlands in rural India. These structures in kitchen gardens are smaller and are commonly located in backyards of houses. Often, they are as small as 6 feet x 6 feet (1.8 meters x 1.8 meters) in size. Such smaller structures are not uncommon in the premises of houses in towns and cities too.Some people use their house or cattle shed as the trellis structure for the climber crops to spread. Different types of backyard trellis structures are depicted in Fig.3. Most of the vegetables from them are consumed by the family members, thus playing a vital role in meeting the nutritional food needs of the family.

3(a) 3(b)

Fig. 3: Types of backyard trellis structures, (a) backyard structure and (b) house roof as trellis

In farmlands, while some farmers erect trellis structures in uplands, others used to construct them right amidst paddy fields in low lands. Some farmers in Uttar Pradesh and Bihar were found cultivating vegetables on trellis structures that are built in the narrower border strips between two plots of main crop, a practice that exhibits optimum use of land while creating a barrier against pest migration across main farm plots (Fig. 4). However, the structures in farmlands normally are much larger in size compared to that in backyards. Many traditional structures were found in areas upto 0.50 acres. Exceptionally, some were built in an area of up to 1.00 acre, either in contiguous fashion or in compartments with narrow separation between each.

3.2. Structural forms of construction

Structurally, trellises are constructed in amazingly different forms and shapes in different locations in India.They reflect the ingenuity and creative capacities of small farmers of India. Very few research studies focussed on the structural forms of trellises, especially that are traditional to India. Kurhekar et al. (2015) constructed and studied different structural forms of bamboo trellises in Konkan region of Maharashtra.

At the first level, structurally we classify the trellises broadly as:

I. Fixed type structures

These are the structures built by digging pits and driving the wooden poles into the ground. They are fixed and permanent in nature and are expected to remain for a minimum of 3-4 years. These are most commonly found in many areas in India.

II. Portable and temporary structures

Structures which are built using poles but without driving them into the ground are quite unique to some vegetable-cultivating clusters in north Bihar. They are easily removable and portable to another location or farmland.

Let us look at the fixed type structures in more detail before reading about the portable structures.The fixed type structures are further categorized as four types, as narrated below:

4(a)

4(b)

4(c)

Fig. 4: Location of trellis structures in farmlands, (a) upland structure, (b) trellis amidst paddy land and (c) border trellis structure

3.2.1. Fixed type structures

Type 1 : Vertical growth trellis

These structures involve erecting rows of wooden or bamboo poles, at equal spacing between them, at a pre-defined spacing between rows. Any locally available pole material is used, including split bamboo. Each row of poles is anchored at the ends, but not linked to the neighbouring rows. Also, no roof is built in this method of construction. All the vegetable growth

takes place on the netted (using either nylon or jute or cotton threads) vertical surfaces on either side of the rows. In terms of cost and effort, these are much cheaper and easier to build (Fig. 5).

5(a)

5(b)

5(c)

Fig. 5: Different practices in Vertical growth type structures, (a) narrow space between rows, (b) wider space between rows with ground crop and (c) use of split bamboo

The spread of the climber crop, such as, bitter gourd, bottle gourd etc., mostly happens vertically. As the structure is open from top, ample sunlight and ventilation benefits in healthy crop growth and better productivity. Crops planted on the ground along the poles in a row have opportunity to spread on the entire vertical netted surface. Studies by Singh et al. (2007) and Saha et al. (2016) found that the vertical type of trellis systems are the best suited for bitter gourd cultivation with the least fruit borer and fruit fly infestations.

Type 2 : Flat roof type trellis structures

This is the most common form of a trellis structure that flashes in everyone's mind. These are constructed by fixing the poles in rows and tying them together, with horizontally placed sticks or poles, at a height of 5-7 feet (1.5-2.1 meters) on both directions. The end vertical pole is provided with additional bracing. Netting is done with either nylon thread or Galvanized Iron (GI) wire.

In this system, the climber vegetable crop predominantly spreads horizontally on the flat roof. The major advantage is that the area on the ground is available for cultivating a ground crop simultaneously or in a relay system[3].

Normally, the height of these structures varies between 5 and 7 feet (1.5 and 2.1 m) with trellis spread in a contiguous manner (Fig. 6). In such cases, there is difficulty in spraying of

[3]The relay system involves planting crops on trellis and on the ground in rotation with some over-lap period. For example, just before harvest and removal of the vine on trellis, farmer plants ground crop. Thus, by the time the ground crop matures and needs more sunlight, the crop on trellis is gone.

pesticides and harvesting of vegetables grown on the upper side of the flat roof. However, there are exceptions to this normal practice with many farmers erecting difficult-to-believe low-height structures in discontinuous manner to cultivate pointed gourd, betel leaf etc., in different parts of India (Fig. 7).

6(a)

6(b)

Fig. 6: Flat roof trellis structures, (a) common type and (b) structure showing wire netting

7(a)

7(b)

Fig. 7: Low-height structures, (a) discontinuous type and (b) continuous type

Obviously, the low-roof structures are easier to maintain and to access different parts of the roof. Another major advantage with them is, they are more stable against the wind forces compared to those with larger heights. But, the ground area under them is not usable for cultivating ground crops. These structures are constructed in low lands on raised beds to prevent flooding in West Bengal and other Gangetic basin areas in India (Fig. 8).

Fig. 8: Raised-bed low-height trellis structure

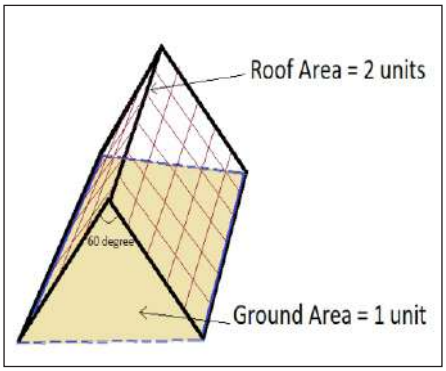
Type 3: Pitched roof structures

The roof of these trellis structures is pitched or slanted, instead of flat in orientation. With this shape, there is no need for vertical supporting poles. These are generally constructed in longitudinal rows with intermittent open space between the two (Fig. 9a & 9b). Bamboo or other wooden poles are used depending on the local availability. The vegetable plants are planted at the feet of these slanting poles and encouraged to climb from both the faces of the pitched roof. With these unique features, these pitched roof trellis structures stand out from all other models. These structures were found in Tamil Nadu, Karnataka and parts of West Bengal in our study.

It is not difficult to guess the motivation behind such a strange-shaped structure constructed by farmers. Since most of the vegetables grow and hang on their weight inside the structure, these structures may be effective in preventing animals eating away the vegetable produce. Another interesting aspect is the availability of larger roof area per unit ground area (Fig. 9c). Hence, the farmer will be able to offer more area for the crop to spread on and produce more for a given ground area.

9(b)

9(a)



9(c)

Fig. 9: Pitched roof trellis structures, (a) in Tamil Nadu, (b) in West Bengal and (c) roof area per unit ground area

Type 4: Arch type structures

If pitched roof structures are amazing, the arch type structures are the weirder ones that we came across in the tribal pockets of Rayagada district of Odisha. Here, some farmers use thinner and pliable culms of bamboo for constructing trellises. The thinner bamboo finds its use here after thicker parts of the mature bamboo are separated for better uses. These elastic bamboo poles are bent to form an arch shape, to introduce stiffness in it, and trellises are erected in longitudinal rows (Fig. 10).

10(a)

10(b)

Fig. 10: Arch type trellis structures, (a) with pointed gourd crop and (b) showing the skeleton

The arch type structures are amenable to cultivation on the ground too. We found farmers growing onion and green leafy vegetables on the ground along with the pointed gourd and ivy gourd on the trellises. Here, it is important to note that the cost of materials and labour in erecting them is the least compared to any other form of trellis. Farmers mostly use the remains of bamboo poles for the purpose.

The diversity in structural forms of trellis construction does not end here. There are three more aspects that exhibit farmers' ingenuity as discussed below:

3.2.1.1. Different trellis heights for different crops

Across all the structural forms, the flat roof type one is the most common and obvious form. However, farmers of different regions vary the height of these structures according to the crop type, climatic conditions (such as, wind speed) and ease of access as well as doing farm operations (Fig. 11). While larger height offers more aeration to crops and ease of moving around under the trellis for the farmer, it requires stronger anchoring of end poles for stability. Lower height structures are easier to build, cost less and access to trellis crops is better. However, they do not permit growing another crop on the ground.

11(b)

11(c)

11(a)

Fig. 11: Trellis structures of, (a) low height, (b) medium height and (c) larger height

3.2.1.2. Orientation and gridding practices

In terms of the orientation of trellis, continuous and discontinuous forms of trellis are equally popular. Some farmers constructed continuous and rectangular-shaped trellises in areas of 0.2 to 0.5 acres, others preferred discontinuous forms that are often oriented longitudinally with intermittent open space (Fig. 12). Such open spaces between trellises are perceived to be a waste of space by some farmers, but some others think that such a gridding practice is vital for preventing the migration of pests from one part of trellis to the other.

12(b)

12(a)

Fig. 12: Different gridding practices in trellis construction, (a) continuous and (b) grid type with open spaces

3.2.1.3. Bracing of end poles

In all the fixed type trellis structures, there will be end poles on four sides in case of rectangular-shaped trellis structures and on two sides in case of the longitudinal trellis structures. Bracing is the practice of tightening and fixing these end poles using GI wires or wooden poles or equivalent so that the structure gains strength and stability. This is essential to protect the structure against wind loads, weight of the crop, impact of heavy rains and accidental dashing by automobiles / animals etc.

There are primarily three methods of providing this bracing support to end poles (Fig. 13):

(i) bracing with GI wire anchored to the ground outside the trellis
(ii) bracing by supporting with wooden poles from inside the trellis, and
(iii) bracing with slanting end poles

The second one has a clear and major advantage of avoiding the loss of land and difficulties in manoeuvring with agricultural machinery and vehicles around the trellis structure.

13(a)

13(b)

13(c)

13(d)

Fig. 13: Bracing support to end poles,
(a) bracing with GI wire from outside, (b) bracing with wooden pole from inside,
(c) bracing with a cement pole from inside and (d) bracing with slanting pole

3.2.1.4. Fencing around the trellis

Finally, different fencing practices deserve a mention. Fencing around the trellis is necessary to wean away grazing animals from eating the crops. Fences are made either using wooden pieces traditionally or using a nylon netting in a more modern way (Fig. 14). Some farmers in Udupi district of Karnataka were found using the nylon nets not only to fence but also to construct temporary trellis-like structures (Fig. 15). These are highly useful in forest-fringes and where there is the problem of animals eating away the crop in the nights. Some farmers also made a small shelter close to the trellis or farmland, to keep a close watch and vigil in the nights (Fig. 16).

14(a)

14(b)

Fig. 14: Fencing around the trellis structures, (a) using wooden poles and (b) using nylon net

Fig. 15: A trellis made using nylon net and PVC poles

Fig. 16: A night shelter made near a trellis structure

3.2.2. Portable and temporary structures

The second major category of trellis structures is portable structures. Farmers in few pockets in Samastipur district (in and around Bibuthinagar block) Bihar, erect these trellis structures, generally on 0.10 to 0.40 acres of land.

The uniqueness of these structures is defined by the following:

- Wooden vertical poles are not driven into the earth
- No horizontal wooden poles are required to tie vertical poles together
- End poles, slanted in position, themselves act as bracing poles
- Bracing with GI wire on all the sides balances the structure.

They are readily constructed in a short span of time and may be shifted to another plot of the farmland at the will of the farmer. We worked with a farmer (Ujwal Kumar Jha) from Kalyanpur village in Bibuthinagar block, Samastipur district, Bihar to re-enact construction of this type of trellis to understand the practice more in detail.

This farmer has a small trellis structure standing in his farm at the time of our visit during Nov 2020 (Fig. 17). The structure was made of predominantly two materials – bamboo poles and GI wires – without making any permanent construction on the site. End poles on all four sides are anchored to the ground using a brickbat buried inside the ground (Fig. 18). All the internal vertical poles of the trellis structure are inserted under the GI wires and raised to the necessary height, but not driven into the ground. This structure is akin to erecting of very commonly seen *shamiyana* tents[4] on festive occasions in India. However, these trellis structurally are many times stronger and stable.

Typically, these structures take a few hours to build and cost a fraction of the cost of a fixed trellis structure. To erect a demonstration structure on a land extent of approximately 1000 square feet, the farmer took around 1.5 hours, and it costed just Rs. 3000, mostly towards the cost of end poles made of iron. If bamboo poles were used, it would have costed even less.

Fig. 19 depicts the sequence of steps in the construction of a small trellis structure in this method:

Fig. 18: End pole tied to the ground level support using GI wire

[4]*Shamiyana* tents are made of cloth and erected temporarily using bamboo poles for few days of use. Picture of a typical tent is available at: https://drive.google.com/file/d/1ZZaR63dw_3LqcrqS3Kh5gvJP9kTKwsTA/view?usp=sharing.

Fig. 17: Typical portable trellis structure made using bamboo poles

19(a) Step 1: Making round pits on the ground

19(b) Step 2: Tying the GI wire to the anchor bricks

19(c) Step 3: Fixing the GI wire with anchor brick in the pit

19(d) Step 4: Tying the GI wire between two end poles

19(e) Step 5: Erecting the slanted end poles

19(f) Step 6: Tightening the GI using a turnbuckle

19(g) Step 7: Weaving the nylon thread

19(h) Step 8: Erecting internal bamboo poles

19(i) Step 9: Planting the pointed gourd seedling

Fig. 19: Construction procedure of a typical portable trellis

Fig. 19(j): Completed trellis structure

3.3. Raw material used for constructing the trellis structures

We came across a variety of materials being used for constructing the trellis, much of it locally available and of tree-sourced. However, bamboo poles are the most versatile material used across India in different States, especially for erecting the skeleton of the trellises. Farmers in West Bengal earlier used the threads made from jute fibre for weaving the net or tying vertical supports for the plants to reach the trellis roof. But, use of various modern materials also creeped into the traditional methods of construction of trellis over recent years. Minor components like wires, threads, nets and irrigation pipes are now coming from nylon and plastic materials.

The following is a brief description of different components of trellis structures:

3.3.1. *Poles and bracing supports*

These are the primary and major components of any trellis structure. Thick and thinner bamboo poles are equally used in building different trellis structures. There is also an innovative use of dried-up tree stems as poles (Fig. 20). Farmers preserve the pole material after their removal for future reuse(Fig. 21).

20(a)

20(b)

Fig. 20: Use of different materials for trellis structures, (a) bamboo skeleton and (b) tree stems used for training the vines

Fig. 21: Pole material stored by farmers for future reuse

3.3.2 Horizontal ties between poles

Generally, the horizontal ties between the vertical poles provided at the top of the trellis are also of bamboo material. However, other locally available tree species are not uncommon in forest fringe areas.

3.3.3 GI wire

GI wire is another most common material used by farmers for bracing the end poles and for tying one pole to another in a row. The use of GI wire is least in the vertical type trellis structures and most in portable type structures.

Fig. 22: Thread used for weaving the net in trellis structures

3.3.4 Nylon or plastic thread for weaving the net

This is another most widely used material across India for weaving the net for the crops to cling to and spread further. Local hardware and plastic material shops offer a variety of these materials, from cheap to expensive ones with different durability properties (Fig. 22).

3.3.5 Fencing material

There are two types of fencing material widely used viz., (i) wooden or bamboo poles and (ii) nylon nets (as shown in Fig. 14). While providing a fence is a choice made by a farmer depending on problem of animal grazing, human thefts etc., the choice of material solely depended on the cost and ease of availability. Generally, places where availability of wooden poles is cheaper locally (or) freely available (from neighbouring forest areas), farmers preferred wooden poles. However, the nylon nets are quite effective in preventing the entry of smaller animals as well as birds through them. Traditional bird scarers are also used by some farmers to dissuade birds from eating crops. It is also worth a mention that the pitched roof trellis structures are found to be effective in preventing the larger free-grazing cattle entering inside them and eating-away the harvest.

Further to the above construction materials used in making trellis structures, there are some others that are ancillary to the function of crop growth on a trellis. Pest control devices, such as traps, got a mention under Section 3.4: Cropping and agronomic practices. Irrigation pipes (flat pipes / HDPE round pipes / drip irrigation lateral pipes etc.) are used for providing water to plants. These are dealt appropriately under Section 3.5: Irrigation practices. Similarly, various small implements used in cultivation are covered under Section 3.6: Tools and implements. Turnbuckle tool, for tightening the ropes or wires tied to two end poles, was already shown in Fig.19(f) under Section 3.2.2.

3.4. Cropping and agronomic practices

Various crop combinations are grown on trellis structures and as ground crop in different seasons round the year. Farmers are quite creative in their crop combinations and rotation practices in India. There are also farmers who do not prefer cultivating a ground crop. In fact, a maze of such practices exists in India, that makes it difficult any attempt to classify or fix it in a theoretical framework. However, a simpler classification into three broad types is presented here:

3.4.1. Single crop on the trellis structure

Monoculture of a climber vegetable crop on the trellis structure is a common practice among farmers in many States of India. The crop on the trellis could be pointed gourd, ivy gourd, bottle gourd, chow-chow, cucumber (green, long) etc. However, simultaneous cultivation of a ground crop also exists in different structural forms of trellises (Fig. 23).


23(a)


23(b)


23(c)

Fig. 23: Single crop trellis systems, (a) bottle gourd on a vertical trellis, (b) chow-chow on a flat roof trellis and (c) cucumber on a pitched trellis

3.4.2. Mixed crops on the trellis structure

Cultivation of two or more crops on the trellis is termed here as mixed cropping. Some farmers in Bihar, Gujarat and Odisha were found to be cultivating combinations of two or more crops on a single trellis (Fig. 24). Added to this is the presence (or) absence of a ground crop. Farmers are of the opinion that these combinations help to over-come price fluctuations of a specific crop in the local market, while getting regular income every week.

24(a)

24(b)

Fig. 24: Mixed cropping system on trellises,
(a) bottle gourd and bitter gourd and (b) pumpkin and long beans

The method of planting such multiple crops also differs from place to place. Some farmers planted all the crops at each pole so that all of them climb together (Fig. 25). Some others preferred to plant different crops in different rows.

Fig. 25: Different vegetable vines trained onto a single trellis

3.4.3. Relay crop system on the trellis structure

As described in Section 3.2.1., a relay crop system works on the principle of rotating different crops on the trellis and ground, with some time-overlap among them. For example, we found some farmers in Khammam district, Telangana, just before the spine gourd crop matures on the trellis, transplanted tomato seedlings from the nursery to the ground under the trellis structure. The trellis crop offers partial cover to the tender tomato plants during their initial days. By the time the tomato crop grows, the trellis crop would completely dry up giving sufficient sunlight to the tomato plants. Thus, the relay systems work well with those ground crops requiring full sunlight. Here, the tomato plants are also trained to the trellis using threads, so that the fruit quality and productivity improves. Chaitanya et al. (2020), from field demonstrations in Khammam district, Telangana, estimated an increase in productivity of around 44% in such a practice compared to ground cultivation of tomato crop.

Crops like turmeric and onion were found to be on the ground overlapping with some or the other crops on the trellises in Araku valley, Visakhapatnam district, Andhra Pradesh and Pratapgarh district, Uttar Pradesh respectively (Fig. 26). Common ground crops found with trellis structures are tomato, potato, onion, turmeric, ginger, cauliflower, okra and cluster beans. However, though a vine crop, we did not come across cucumber (yellow, round) being grown on trellises anywhere. Farmers of Anantapur district, Andhra Pradesh grow them on the ground (Fig. 27).

26(a)

26(b)

Fig. 26: Crops grown in relay system, (a) turmeric and (b) onion

Fig. 27: Cucumber (yellow, round) grown on the ground

Another useful classification of crops on trellises is based on the duration of the crop:

(i) seasonal crops, and
(ii) perennial crops

There are some gourd species, such as, pointed gourd and its look-alikes (such as, ivy gourd) have a peculiar quality of surviving for 2-3 years with multiple fruitions across seasons. Once planted, the vine plant remains on the trellis for a few years. For multiplying such species from one farmland to the other, farmers collect cuttings from healthy plants and grow them in polyethylene packs filled with soil (Fig. 28).

Fig. 28: Cuttings of ivy gourd raised in polyethylene packs

In contrast, many other crops such as ridge gourd, sponge gourd, bottle gourd, bitter gourd etc., require sowing every season. However, farmers tend to preserve the seeds from one season to the other for replanting or raise seedlings in their nursery before transplantation (Fig. 29).

29(a)

29(b)

Fig. 29: (a) Seeds of ridge gourd and beans preserved by farmers and (b) nursery raising

3.4.4. Other agronomic practices

Other key agronomic practices that were observed from different locations are:

3.4.4.1. Weed removal practices

Weed growth on the ground is equally a problem for the trellis farmers. Growth of weeds on the ground tend to compete with the vegetable crops for nutrients and stunt later's growth. While most of the small trellis farmers tend to remove weeds manually using small tools, larger area farmers find herbicide sprays to be more convenient and cost-effective (Fig. 30).

30(a)

30(b)

Fig. 30: Weed removal by farmers, (a) using a small hand tool and (b) using a manual implement

3.4.4.2. Nutrient management

Application of NPK[5] complex fertilizers is quite common to farmers. However, the dosages varied widely from place to place. Small farmers in remote tribal pockets of Jharkhand and Chhattisgarh are the ones with the least affinity to apply any external fertilizer inputs. There are quite scholarly farmers who took to organic methods of nutrient management as the way of life, but they are rare. Use of compost and vermi-compost as a supplement for soil health management is quite popular with some large farmers having their own composting units (Fig. 31).

Fig. 31: Vermi-compost unit in Samastipur district, Bihar

[5]NPK stands for Nitrogen (N), Phosphorous (P) and Potassium (K), which are the primary nutrients required for the healthy growth of plants

32(a)

32(b) Fig. 32: Pest infestation in (a) ivy gourd and (b) ridge gourd

3.4.4.3. Pest and disease management

Pests and diseases are persistent problems that vegetable cultivating farmers face across the study locations. A field study on 120 trellis cultivation farmers by Balaji et al. (2017) in Coimbatore district, Tamil Nadu confirms that pest management followed by increasing cost of fertilizers and seeds are the major problems faced by farmers. Crops grown on ground are more susceptible to attacks of pests of soil origin. These pests of different insect orders, such as, *Coleoptera* (beetles), *Lepidoptera* (moths and butterflies) and *Diptera* (flies), spend part of their lifetime in soil (Beneficial Insectary 2020). However, crops on trellises are also susceptible to various pests and diseases to a lesser extent compared to that in ground crops (Fig. 32).

Azad et al. (2013) found that botanical pesticides prepared from mahogany (*Swietenia mahagoni*) and chirata (*Swertia chirata*) leaves applied on cucumber crop were effective not only in pest control but also helped in plant growth. However, there is not much field practice of such botanical pesticides being used on crops grown on trellises. Sangeetha et al. (2016) concluded that growing pointed gourd on trellises significantly reduces the leaf, vine and fruit rot especially in rainy season, compared to that grown on soil beds.

Apart from providing separation space between trellis structures, we observed the practice of using *aushadhiya matka khad*[6] as plant growth promoter and pest repellent in Ranchi district, Jharkhand. We came across few farmers in Navsari district, Gujarat and Yadadri Bhuvanagiri district, Telangana using pheromone and sticky traps that are available in local markets respectively (Fig. 33).

[6] a preparation locally made by fermenting a mixture of cow urine, cow dung, neem oil and karanj *(Pongamia pinnata)* seed extract

However, there is no significant cross-learning from these farmers to others within the study area. For each such a farmer, there are many not using such traps. Ability to recognize different pests and diseases is observed among farmers. But they entirely depend on the local pesticide shops for prescription of chemical sprays. Invariably, every farmer we met possessed a chemical sprayer, either of manual operation (or) powered by petrol (or) operated by a charged battery (Fig. 34).

33(a)

33(b)

Fig.33: Use of traps (a) Pheromone trap used in bottle gourd crop and
(b) Sticky trap used in bitter gourd crop

34(a)

34(b)

Fig. 34: Different sprayers used by farmers,
(a) a low-cost model and (b) manual type sprayer

3.4.4.4. Marketing of produce

Vegetables grown on either land or on trellises are harvested and sold, as frequently as every day. For small farmers, the produce is too little to get wholesale traders to lift the produce from the farm gate. Most of the small farmers harvest the produce during small hours of the day and carry it themselves on bicycles, small carts or hired autos for selling in nearby markets (Fig.35). Direct retailing by small farmers in nearby vegetable markets is also observed, but selling to traders in the market is a more wide-spread practice. The produce pooled will be shifted to bigger trucks by these traders for further transport to nearby towns and cities.

35(a)

35(b)

35(c)

35(d)

Fig. 35: Farmers harvesting vegetables for selling in local markets, (a) to (d)

3.5 Irrigation practices

Watering the vegetable crops in close frequency is necessary for their growth and good vegetable yields. Normally, irrigation is required 1-3 times in a week depending on the local soil type, moisture availability, crop type and climatic conditions.

There are primarily two methods in wider use by different farmers for providing irrigation water to vegetable crops on trellises:

- Open channel irrigation
- Micro irrigation

Open channel irrigation is the most primitive one and widely practised by farmers. Small channels are made to run closer to the rows of vegetable plants offering continuous supply of irrigation water. There are varying practices of open channel irrigation according to the soil type, land slope, and water requirement of crops (Fig. 36). Smaller channels taking off from the main channel in a raised bed vegetable cultivation may be observed in Fig. 8.

36(a)

36(b)

Fig. 36: Open channel irrigation, (a) in a ridge-furrow system and (b) through shallow channels along the rows

Source of irrigation water is another important aspect observed as a part of this pan-India study. Cultivating vegetables depending on rainfall alone is not uncommon in tribal areas in Chhattisgarh and Odisha. However, every other farmer is convinced that a reliable source of water is a basic necessity for a peace-of-mind trellis vegetable cultivation. Irrigating with water pumped out from open wells and deep bore wells is most common. Also, farmers in some parts of Odisha traditionally practise manual lifting of water from shallow open wells using *tenda*[7] structures (Fig. 37). However, use of water from irrigation canals or water harvesting ponds is a rarity and this study did not find it as a prominent practice.

[7] *Tenda* is a local word used in Odisha that represent a wooden lifting device used to lift water in small quantities from a shallow well and irrigate crops in small pockets of farmland.

Fig. 37: Traditional *tenda* used to lift water from a shallow open well in Kalahandi district, Odisha

The second type of irrigation method is micro irrigation. Drip or sprinkler irrigation units are used to irrigate the crops on trellises. However, though expensive, drip systems are widely used compared to the sprinklers that are much cheaper and portable (Fig. 38). This could be due to the obvious advantages of drip systems, such as, (i) higher water use efficiency, (ii) durability of the system after one-time installation and (iii) less labour intensive and operationally convenient. Within the drip irrigation models, some farmers constructed elevated storage tanks at the trellis for dispensing water to the drip system instead of pumping out water from wells directly. This could be due to unreliable electricity supply in the area or in case of diesel powered wells.

38(a)

38(b)

Fig. 38: Drip irrigation systems used in trellises, (a) elevated storage tank model and (b) direct pumping system with above ground level PVC piping

Fig. 39: A drip irrigation unit with a venturi for fertigation

Fertigation using drip systems in trellis practice is another aspect we observed mostly in south India. Farmers were found applying water-soluble chemical fertilizers, such as, Urea, using venturi apparatus that works on the principle of differential pressure (Fig. 39).

40(a)

Fig. 40: Plastic mulch sheets in trellis cultivation, (a) only mulch sheets and (b) drip system and mulch sheet

Use of plastic mulch sheets, to reduce loss of soil moisture due to evaporation and to suppress weed growth, is yet another case of invasion of plastics into the traditional trellis cultivation practices (Fig. 40). This could be a stand-alone practice or in combination with the drip system.

40(b)

41(a)

Fig. 41: PVC pipe irrigation, (a) simple outlet and (b) outlet with a small storage tank

A third and less widely used method is the 'pipe irrigation' method. A network of PVC pipes laid underground across the farm land provides irrigation water through conveniently located outlet points (Fig. 41). But this system is not found in the farm fields widely at any of the study locations.

41(b)

There is the fourth and unique practice of reuse of excess water that drains out from surrounding paddy fields. Amin et al (2015) and Hasan et al. (2009) studied the combined cultivation of paddy and vegetables and established their profitability for different vegetables. We found in West Bengal and Uttar Pradesh, farmers erecting trellis structures amidst paddy fields and cultivating vegetables, using the excess drain water from the paddy fields. In such cases, mostly irrigation happens from a combination of natural rains and the excess water from paddy fields during monsoon as well as winter (Fig. 42).

42(a)

42(b)

Fig. 42: Reuse of water from paddy fields, (a) in Birbhum district, West Bengal and (b) in Gorakhpur district, Uttar Pradesh

3.6. Tools and implements

Trellis cultivation farmers were found using a variety of small tools and implements in agriculture. These tools are for removing weeds, ploughing, ground preparation for seeding, spraying pesticides, splicing the GI wires and tightening etc.(Fig. 43). Most of these tools were designed by farmers themselves. They got them fabricated as per their ideas and needs at the local village artisans.

Farmers are quite innovative in devising the tools tailored to their purpose. As there is no commercial purpose behind such innovations, most of the innovations by such farmers do not cross the boundaries of their villages. This study could not cover the tools and implements used by farmers in more detail due to the smaller number of sample farmers. However, we believe that there is a great potential for this becoming the subject of future studies by WLF.

(a) Rake for loosening and levelling soil

(b) & (c) Digging hoe

(d) & (e) Hand harrow

(f) hand tool to make pits

(g) Turnbuckle to tighten wires and ropes

(h) Wheel hoe and weeder

(i) & (j) Hand tools for digging and weed removal

(k) Sickle and other smaller tools

Fig. 43: Various tools and implements used by small farmers

4. Conclusion

Portable trellises to permanent trellis structures, both in kitchen gardens and in farmlands, are quite diverse in their construction and agronomic practices across India. Use of local materials, such as, different parts of bamboo trees, stems of locally available trees in trellis cultivation makes this practice simple, low-cost and ecologically sustainable.

Climatically, rainfed as well as irrigated trellis cultivation practices exist across India. However, availability of an irrigation source, most often an open well or a bore well, certainly helps the farmer to grow multiple crops across seasons, compared to a farmer entirely depending on rains.

One uncontested notion among all the farmers is that trellis cultivation improves the quality of produce; increases the productivity by 100 to 300%; and thus, increases the net returns dramatically. These feelers from the ground reinforced our resolve to dispel the myth that trellis construction is an expensive affair and popularize the trellis practice among small farmers so that they make 'substantial' gains in their income. However, pest infestation and uncertain market prices are the two major challenges faced by small trellis farmers across India. Experiences of *Covai* Pandal Vegetable Growers' Association in Coimbatore, Tamil Nadu, if studied in further detail, may offer valuable insights (Balaji et al. 2017).

It is interesting to note that some vegetables are grown on the ground traditionally, are grown on trellis elsewhere and vice-versa. For example, the study finds that ash gourd and pumpkin are grown on the ground between two rows of a trellis in many areas. But there are also occasions where farmers grow them on trellis structures. It is also not well-understood why certain vines, like cucumber (yellow, round), not being grown on trellis structures. Probably, the potential of such crops cultivated on trellis is not yet unlocked!

The concept of trellis cultivation using cheap and local materials appears quite simple yet is a powerful way to make agriculture remunerative particularly for the farmers with tiny land holdings. Farmers will be able to double cropped area and consequently increase their farm income, by cultivating several crops on trellis and on the ground below the trellis structures simultaneously. Standardization of designs and costs may whitewash the ingenuity in traditional practices. Therefore, it is important to consciously preserve diversity in traditional trellis practices, while offering subsidies through Govt. schemes.

To sum up, the journey across India with the farmers cultivating vegetables in traditional trellis methods has been quite enriching and helped to expand the boundaries of our imagination of India. With a strong conviction, we feel that this journey shall extend to various other facets of India in future efforts.

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Appendix 1

Scientific names of different vegetables cultivated on trellis structures

Vines:

Ash gourd (also, Wax gourd / White gourd) - *Benincasa hispida*

Betel – *Piper betle*

Bitter gourd - *Momordica charantia*

Bottle gourd - *Lagenaria siceraria*

Broad bean (also, field bean / horse bean) - *Vicia faba*

Chow-chow (also, Chayote / Cho-cho) - *Sechium edule*

Ivy gourd (also, Little gourd) – *Coccinia Grandis*

Kheera cucumber and yellow cucumber /lemon cucumber – *Cucuis sativus*

Long bean (also, Snake bean) *Vigna unguiculata subsp. Sesquipedalis*

Pointed gourd – *Trichosanthes dioica*

Pumpkin - *Cucurbita pepo*

Ridge gourd - *Luffa acutangula*

Snake gourd - *Trichosanthes cucumerina*

Spine gourd – *Momordica dioiea*

Sponge gourd - *Luffa aegyptiaca*

Ground crops:

Cauliflower **–** *Brassica oleracea*

Cluster bean – *Cyamopsis tetragonoloba*

Ginger –*Zingiber officinale*

Okra (also, Lady's finger) –*Abelmoschus esculentus*

Onion –*Allium cepa*

Potato - *Solanum tuberosum*

Tomato -*Solanum lycopersicum*

Turmeric - *Curcuma longa*

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