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Vertical intensification of rice ecosystems: Integrating cucurbits through multi-storey sack-trellis farming

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Accelerated urban expansion, shrinking cultivable land and increasing climatic uncertainties have intensified pressure on rice-based agro-ecosystems of India, particularly in flood-prone lowland areas. With limited scope for horizontal expansion, escalating productivity per unit area through vertical intensification and efficient resource use has become essential. The sack-trellis system is a climate-smart, low-cost cropping approach that integrates trailing cucurbits above standing lowland rice during kharif *season. This article discusses the production technology and benefits of viny vegetables grown on trellises alongside rice crop. The system improves cropping intensity, farm income, nutritional security and resource-use efficiency while reducing soil-borne diseases without disturbing rice growth.*

Keywords: Additional income, Cucurbitaceous vegetables, Lowland rice, Multi-storey cropping, Vertical space intensification

IN a densely populated country like India, many crop cultivation intensification in less favoured ecosystems, viz. hilly tracts, dry areas, marshy lands and coastal tracts are under carefully planned and scientifically managed agricultural systems to meet food security. However, any additional expansion of crop production through horizontal intensification of cultivated area has become a bottleneck. Under such constraints, ensuring food, nutritional and financial security of the country's escalating population is the focal goal of the agricultural scientists and planners. The issue of long-term sustainability of agro-ecosystems without hampering the ecological balance should also have to be sincerely brought under consideration. At present, around 14.4 million ha of land (approximately 32% of the total area) under rice in India is usually covered by low land rice grown under submergence. In many rice-growing regions of India, highly productive alluvial soils are sometimes met with heavy monsoon rainfall resulting in frequent flooding during *kharif* season. Under such circumstances, farmers are often compelled to cultivate lowland rice. However, changing climatic conditions and rising input costs have made the marginal and small farmers to realise the necessity of enhancement in both cropping intensity and economic returns from their limited as well as stressed land resources. The prolonged submergence in lowland rice ecosystems restricts the integration of additional crops under conventional ponded conditions, thereby limiting diversification options. To address these constraints, multi-storey cropping systems have gained attention as a resource-efficient approach. In particular, the sack-trellis system facilitating vertical crop layering within the same field enables optimal utilisation of space, light and nutrients. This system enhances biomass production per unit area, unit time and unit input leading to improved system productivity, higher farm profitability and rich agro-biodiversity, while maintaining the sustainability of rice-based cropping systems.

India is one of the leading vegetable-producing countries in the world, blessed with versatile agro-climatic conditions favouring cultivation of a panoramic range of vegetables. However, vegetables are prone to pest attack especially in *kharif* season. Through such multi-storey system, the menace of pathogenic infestation among vegetables grown in close contact

Cucumber + rice grown in sack column trellis system

Bottle gourd fruits hanging from trellis above rice crop

with the soil surface may largely be reduced. Inclusion of cucurbitaceous vegetables alongside staple food crop in rice-based cropping systems ensures household nutritional security through assured access to farm fresh vegetables rich in dietary fibre, vitamins and essential minerals. Regular availability of such vegetables helps in diversifying domestic diets and reducing reliance on market-purchased foods. Sack-grown cucurbits effectively utilise the affluent water available in rice fields, thereby, improve water use efficiency. Growing rice and cucurbits in separate soil strata brings no competition for nutrients, water and even air except for light due to partial mutual shading. Extensive research on plant population of cucurbits as column grown intercrop in rice ecosystem is being carried out for reducing the effect of such mutual shading to the highest extent.

Sack-trellis system

The sack-trellis system is a low-cost, climate-smart and multi-storey cropping approach in which trailing vegetables are grown in soil and nutrient-filled sacks placed along the bunds and ridges or even in ponded areas of lowland rice fields, wherein the vines are trained upward on various types of trellis erected around 6 feet (1.8 m) over the standing rice crop. All such vegetables, viz. bottle gourd, cucumber, ridge gourd, snake gourd, bitter gourd, etc. suitable for rainy season can successfully be cultivated in this system. The sack-trellis system facilitates simultaneous production of rice and vegetables by integrating column planting with vertical vine training. Thus, it enhances cropping intensity and farm income, providing a practical diversification option for marginal and small farmers in flood-prone rice-growing regions.

Trellis types

Trellis systems are widely used in vegetable cultivation to support the climbing and vining of trailing crops, improve canopy architecture and enhance resource use efficiency. Horizontal trellises provide overhead support allowing vines to spread laterally and form a uniform canopy, thereby improving light interception and ease of intercultural operations of cucurbits. For e.g. vine pruning, vine shaping, vine positioning, pollination management, etc. Skipped trellis systems is one of the types characterised by intermittent or spaced support structures which reduce structural cost while maintaining adequate vine support and airflow resulting in better microclimatic conditions in the base crops. In contrast, vertical trellis systems train vines upward along ropes or wires, enabling efficient utilisation of vertical space and facilitating crop management and yield optimisation.

Spacing details

As vegetables are grown as an intercrop above rice or along its border, appropriate spacing must be maintained to avoid excessive shading in rice crop and to ensure adequate light interception to the rice canopy. Depending on the spreading behaviour as well as above-trellis, vegetative growth of the vines cucurbitaceous plant population varies. On an average around 2,500–3,000 cucurbitaceous plants should have to be accommodated above one hectare of the rice field or along its field borders (sack to sack spacing: around 2 m). Sacks duly filled with soil-manure mixture are placed along the peripheral field border or well-maintained ridges inside rice fields or can be kept inside the ponded rice fields. Proper spacing improves air circulation within the crop canopy, thereby reducing humidity-induced disease and pest as well as lodging of rice crop.

Setting up sacks

Polypropylene woven sacks (50 kg size) usually used for keeping and storing rice, sugar or fertiliser can be reused in column cultivation of cucurbits in rice fields under trellis system. At the beginning of the monsoon season, each sack is to be filled with a uniformly mixed growing medium comprising of about 40 kg of dry soil and 10 kg of organic manure to provide the trailing plants with sufficient nutrients and support healthy root growth. To prevent stagnation of excess rainwater, three to four small drainage holes should have to be kept at the bottom of each sack. Once prepared through such procedure, the sacks should have to be kept inside a shaded area until sowing of vegetable seeds or transplanting of its seedlings already raised *ex-situ* would be completed. This measure is adopted for avoiding nutrient loss

Setting sacks in the field

Skip/spaced trellis system

Vertical trellis system

and washing out of soil due to heavy rainfall.

Nutritional nourishment of crops

The main crop i.e. rice is to be nourished following the conventional recommended fertiliser dose and schedule. However, for vegetable cultivation in sacks, each 50 kg sack is to be prepared by mixing around 10 kg farmyard manure or well decomposed cattle manure or vermicompost with 50 g NPK (10:26:26) as a basal dose. During the duration of the entire crop growth, top-dressing is to be carried out by applying 20 g urea per sack at 21–28 days after vine planting and it is to be followed by a second top dressing of 20 g urea and 15 g muriate of potash at 42–45 days after planting. These fertilisers should be applied slightly away from the plant base and are to be incorporated into the soil using a hand hoe to ensure efficient nutrient uptake.

Managing rain water

During the monsoon period, rice fields usually do not require supplemental irrigation; however, in the event of early monsoon cessation, one or two protective irrigations can be applied as and when required. During monsoon months, the trailing plants nurtured in the sack columns do not require any artificial application of water, because the porous soil-manure mixture in the sack column facilitates capillary rise of water from the ponded rice field, maintaining adequate moisture for vine growth. Nevertheless, it is to be mentioned that such capillary fulfilment would be required only when water saturation in the column through captured rainfall in the sack would be at deficit level. As crop growth progresses, the roots proliferate across the column and finally penetrate the sacks at the bases and rush into the underlying soil enabling efficient squeezing out of water and mining of nutrients from the soil profile beneath the sacks simultaneously. Moreover, during periods of heavy monsoon rainfall, special attention is to be focused on checking whether the small drainage holes made at the base of the sacks at the time of placing are remaining intact or not. If not, those should be made proper.

Training and pruning

These intercultural operations are required for proper spiraling cum climbing of the vines from the sacks to the trellis and reshaping the cucurbitaceous canopy in the interest of thorough light interception across the multi-storey system. The tips of the primary and secondary vines are pruned every fifteen days interval for increasing the female flower flush in all types of branches which ultimately would increase the number of cucurbitaceous fruits. The cut vines such collected are marketed at high price as fresh leafy twigs which are highly nutritious and tasty too if proper culinary process is followed.

Picking and reaping

Picking of fruits at tender stage (edible maturity) is usually initiated at 35 days after sowing of vegetable crop depending on the cucurbitaceous species and cultivars as well. Otherwise, delay in harvesting results in over maturity, rather hardiness of fruits which ultimately makes them unsuitable for marketing or cause decline in market price. Keeping few over matured fruits on the trellis is required only when seeds are to be collected and stored from the indigenous varieties for next year utilisation. Since cucurbits exhibit a non-synchronous growth, blooming and fruiting habit, multiple harvests at 4–5 days intervals are recommended to ensure optimum yield and quality as well as feed regular market demand. In contrast, when all the rice plants grown underneath attain physiological maturity, harvesting should be carried out following stipulated

Ridge gourd + rice grown in sack column trellis system

procedures either by sickles or small reaping instruments.

Additional income and employment generation

A large group of farmers is of the opinion that cultivation of common rice cultivars does not fetch satisfactory profit. Declining factor productivity especially reduced nutrient use efficiency, water use efficiency as well as pest menace are some of the root causes behind such reduced yield of low and medium low land rice. Despite this issue, the farmers cannot withdraw themselves from rice farming because rice is the source of their staple food throughout the year. In addition, rice becomes the only crop that can withstand stagnated water in the fields during monsoon. Therefore, completely replacing rice with other remunerative cash crops is not a feasible option for these farmers, as it would compromise their household food security. For these reasons, the options for earning additional income from their agricultural lands are intensification of cropping through introducing versatile crops in sequence, intercropping, multi-storey cropping, integrated farming, etc.

Cultivation of cucurbits in sack-trellis system in association with transplanted *kharif* rice is more remunerative than sole rice farming. In this context, most of the materials required in sack-trellis system establishment can easily be available at the household level of the marginal and small farm families. So, the initial structural costs can effectively be reduced in the starting year and if the trellis would be maintained properly, it can be reused not only in the next seasons (*rabi* and summer) but also in the succeeding 3–4 years. Some demonstrations noted that this system from one ha can provide an additional amount of ₹1.5 lakh gross returns apart from getting ₹1.4 lakh from rice (grains and straws of paddy, and fruits and leafy vine twigs were considered as marketed products). The gross return of ₹2,90,000/ha, net return of ₹1,76,000/ha and B-C ratio of 2.55 was computed from such cropping system. Growing cucurbitaceous vegetables in rice fields along with regular nurturing, training, pruning and above all multiple picking throughout the growing season generates substantial employment opportunities. The cheerful and spontaneous involvement of the farm women and other family members in this system are creating an overwhelming impact in the adjoining farming community.

Aerial view of sack-trellis multi-storey system

Harvested bottle gourd for marketing

SUMMARY

Despite the substantial advancements in Indian agriculture following multiple sectoral revolutions (Green, White, Blue, Yellow revolution, etc.), persistent challenges continue to constrain sustainable food production. Declining food productivity, soil degradation, erosion, problem soils, erratic rainfall, climatic variability and evolving pest dynamics have been identified as major limiting factors in rice-based production systems. In this context, climate-smart and low-cost technologies supported by effective extension mechanisms are considered essential for enhancing productivity, resilience and livelihood security. The sack-trellis system has been developed as a multi-storey cropping approach for flood-prone lowland rice ecosystems; wherein trailing cucurbits are cultivated in soil-manure filled sacks placed along bunds or within ponded fields and trained on trellises erected above the rice canopy. Through this arrangement, vertical space is efficiently utilised without interference with rice growth. Cropping intensity, resource-use efficiency, nutritional availability and farm income have been observed to improve under this system. Capillary water movement supports vegetable growth and recycled sack media enhances soil organic carbon and nutrient cycling afterwards. Although there are constraints related to investment, management and market linkages, this approach is regarded as a promising strategy for sustainable diversification and climate-resilient agriculture among small and marginal farmers in India.

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