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Tuber crops based cropping system for western Himalayan region of India

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Abstract

To study productivity, profitability, livelihood, and sustainability, the traditional maize-wheat system was compared with a cropping system, including tuber crops on a 1.0 ha area. The percent share of tuber crops and other horticultural crops was 35.84%. The major tuber crop in the studied system was elephant foot yam. The total elephant foot yam equivalent yield in the existing maize wheat system and cropping system involving tuber crops were 27.33 q ha^{-1} and 59.07 q ha^{-1}, respectively. The gross returns were more than ten times higher in the studies system over the existing maize-wheat system. Production efficiency of cropping system involving tuber crops was increased by two times over the maize-wheat system. The study model can be replicated over different locations by inclusions of site-specific agri-enterprises.

Keywords : Cropping system, Tubers, Vegetable, Cereals, Diversification, Sustainability

Introduction

Hill agriculture faces challenges due to a heavy reliance on traditional rainfed systems and cereal-centric crop cultivation, leading to low productivity and minimal farm returns. Maize-wheat is the most often adopted cropping system, causing reduced crop cycles in a year and even longer durations, making agriculture unsustainable. Therefore, wider adoptions of cereal-cereal cropping systems need special consideration. When farmers prioritize mono-cropping without considering the environmental impact, it can result in a depletion of resources and reduced productivity (Lu et al., 2019). This challenge is particularly significant for small and disadvantaged farmers in the western Himalayas, where maize-wheat farming is prevalent. Therefore, agriculture diversification is essential to achieve economic and environmental sustainability and the integrated farming system is one approach that employs a circular economy to promote ecofriendly and sustainable farming practices (Lal, 2020).

Integrating crops and allied agri-enterprises in a location-specific manner has several benefits for small and marginal farmers. This approach can enhance agricultural productivity and sustainability by ensuring that the mix of crops and related enterprises such as livestock, fisheries, poultry, and agroforestry are well-suited to the local environment, natural resources, and markets (Rathore et al., 2008). Therefore, besides ensuring long-term sustainability, it also helps secure nutritional security by making different foods available. An integrated cropping system offers a wide range of food choices, simultaneously maintaining ecological sustainability and promoting food security and resilience. This approach helps to promote diversified production,

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fulfilling dietary and economic requirements, and enhancing food security. However, a locally tested package of practices of different components must be available to execute a model cropping system. It involves location-specific technologies for different cropping seasons under existing natural resources. Therefore, a cropping system based on tuber crops was evaluated for its effectiveness in improving small and marginal farmer's livelihood and environmental sustainability. Tuber crops, especially elephant foot yam and taro, are grown, but scientific cultivation techniques are lacking; otherwise well suited under existing rainfed conditions. A very high demand for elephant foot yams was also observed in the regions for quality planting materials. Therefore, a tuber crop-based cropping system was introduced at the farmer's field for to study the farm economics and sustainability.

Materials and Methods

Site Description and Prevailing Weather conditions

A case on the cropping systems, including tuberous vegetables under the All India Co-ordinated Research Project on Tuber Crops (AICRP TC) was studied in a farmer's field by the AICRP TC center at Research Sub Station (RSS), Bilaspur at Berthin during 2022-2023. The site selected was in the village Fagog, P.O. Baloh, Tehsil Jhandutta, District Bilaspur, Himachal Pradesh. It is located at 31012'30''N latitude: 76023'45'' E longitude, and 650 m above mean sea level. The site comes under the Western Himalayas with a sub-tropical characteristic of a hot summer and cold winter. The site was marginally utilized for crop cultivation and, hence, a non-intensive agro-ecological site. The soil of the selected site belongs to the loamy sand (medium in depth).

Treatments

An area of 1.0 ha was undertaken to study the effect of two modules on productivity, profitability, livelihood, and sustainability. The existing maize-wheat system was compared with the cropping system, which included tuber crops as significant crops (Table 1). Under the studied cropping system, agri-horti system, different crops, elephant foot yam + greater yam + taro + ginger + turmeric + maize-cauliflower + late wheat + cucurbits were compared with the existing maize-wheat system. The details of the treatments of various cropping system modules and area allocation have been provided in Table 1 and Table 2. Standard recommended practices were followed for managing component crops in a cropping systems mode and other allied activities (Table 1-3). Observations were recorded and system livelihood index (Equation1), system profitability (Equation2) and production efficiency (Equation3) were calculated (Shyam et al., 2023) as given below:

$$\text{System Livelihood Index} = \frac{Net\ Returns - Standard\ Deviation}{Maximum\ net\ returns\ attained\ in\ any\ module} \quad \ldots \text{Eqn (1)}$$

$$\text{System Profitability Index} = \frac{Net\ returns\ (₹^{-1}\text{ha}^{-1})}{365} \quad \ldots \text{Eqn (2)}$$

$$\text{Production Efficiency } (₹^{-1}\text{ha}^{-1}\text{ day}^{-1}) = \frac{System\ Productivity\ (\text{kg ha}^{-1})}{365} \quad \ldots \text{Eqn (3)}$$

Table 1. Cropping systems and its various components

Sl. No.	Treatment	Field Crops	Vegetable Crops	Vegetable Nursery	Tuber Crops
1	Maize-Wheat system	√			
2	FC+VP+PSP+LS	√	√	√	√

Results and Discussion

Agronomic productivity of cropping system module

Significant differences were noted in the agronomic productivity and elephant foot yam equivalent yield (EFEY) between the two cropping system modules (Tables 4 and 5). The highest agronomic production (with values of 11493, 12351, and 2967 kg ha^{-1}) and elephant foot yam equivalent yield (with values of 17791, 32975, and 8307 kg ha^{-1}) were achieved in the cropping system module involving tuber crops. In the tuber-based farming system, the system elephant foot yam equivalent productivity (SEFYEP) was 59074 kg ha^{-1}. A 116.09% increase in the SEFYEP was achieved in the elephant foot yam+ greater yam + taro + ginger + turmeric + maize-cauliflower + late wheat + cucurbits compared to the maize-wheat system. The integration of different enterprises in the system notably boosted the farm's gross income from ₹1,68,544 to ₹11,93,633 (Table 6). Furthermore, the elephant foot yam+ greater yam + taro + ginger + turmeric + maize - cauliflower + late wheat + cucurbits system exhibited a seasonal increase of 163.29% during the rainy season and 188.84% during the winter season, outperforming the maize-wheat system (Table 6). The production efficiency of the studied system was higher (161.84 kg ha^{-1}day^{-1}) over the maize-wheat system (74.89 kg ha^{-1} day^{-1}) (Table 6).

Productivity, economics, livelihood and employment generation of cropping system modules

The productivity of the two modules under the cropping

Table 2. Area allocation (m^2) for different modules on a hectare basis of the cropping systems model

Module	Treatments	Field crops	Open field vegetable cultivation	Vegetable seedlings cultivation	Tuber crops cultivation	Total area (m^2)
M1	Maize-Wheat System	10000	-	-	-	10000
M2	Maize+Elephant foot yam+ Greater Yam + Taro + Ginger + Turmeric-Cauliflower+Late wheat+Cucurbits	3451	2515	450	3584	10000

M1: Area (m^2): Maize (Kharif season) -10000; Wheat (Rabi season)-10,000

M2: Area (m^2): Kharif-Maize- 3451; Elephant foot yam-2000; Greater Yam- 600; Taro-984; Ginger-800; Turmeric-1715; Vegetable Seedlings-450 – Rabi- Late Wheat- 3451; Cucurbits- 1715; Cauliflower- 4384; Vegetable Seedlings-450

Table 3. Crops, varieties, spacing and fertilizer schedule adopted for cropping systems trial

Sl. No.	Crops	Crops Growing period	Variety	Spacing (cm^2)	Seed Rate (kg ha^{-1})	Fertilizer consumption
	Maize-Wheat					
1	Maize	May-October	Him Makka-1	60×15	20 kg ha^{-1}	120:60:40
	Wheat	November-April	HPW-368	20×10	100 kg ha^{-1}	120:60:60
2	Elephant foot yam+ Greater Yam + Taro + Ginger + Turmeric +Maize-Cauliflower+Late Wheat Cucurbits					
	Elephant foot yam+ Greater yam + Taro + Ginger + Turmeric +Maize	June-December	Gajendra	90×90	7500.00	100:80:100
			Sree Kartika	90×90	2500.00	120:80:180
			Local	60×45	2500.00	100:50:100
			Himgiri	60×45	2000.00	120:80:100
			IISR Pragati	20×10	100.00	120:60:40
			Him Makka-1	20×10		
	Cauliflower+Late Wheat+Cucurbits	December-May	Pusa-301	60×45	0.25	120:75:60
			Palee F1	120×60	100.00	4.201852
			Punjab Naveen	120×60	5.00	200:100:100
			HPW-368	20×10		

system model varied significantly (Table 6). Including different enterprises in the system notably increased the farm's gross income. The cropping system modules based on tuber crops recorded a higher gross return (₹ 11,93,633). The economic analysis of the two systems revealed that the elephant foot yam+ greater yam + taro + ginger + turmeric +maize- cauliflower + late wheat + cucurbits system generated net returns of ₹ 7,28,170, a benefits-cost ratio of 2.56, and a system profitability of ₹ 1995 $ha^{-1}day^{-1}$ (Table 6). The horticulture-based cropping system, including tuber crops, yielded a significantly higher net return of 994.74% over the maize-wheat system. The higher market price of an acrid-free variety of elephant foot yam and greater yam, along with the demand for planting material, were key factors contributing to the increase in farm income. Furthermore, the tuber crop-based farming system exhibited the highest benefits-cost ratio (1: 2.56) and increased profitability (₹ 1995 $ha^{-1}day^{-1}$). In contrast, the maize-wheat system's sustainable livelihood index (SLI) remained negative (-0.34). Comparing the two systems, the tuber crop-based farming system is more sustainable

Table 4. Agronomic yield of different crops under studied cropping system modules

Sl. No.	Cropping Module	Crop	Area (ha)	Agronomic Yield (t ha^{-1})	EFYEY*
1.	Maize-Wheat	Maize	1.00	4.37	12.60
		Wheat	1.00	4.28	14.73
2.	Elephant foot yam+ Greater yam + Taro + Ginger + Turmeric + Maize -Cauliflower+ Late wheat +Cucurbits	Maize	0.35	1.1	3.50
		Elephant Foot Yam	0.20	5.37	5.37
		Greater Yam	0.06	1.32	2.56
		Taro	0.09	2.26	4.52
		Ginger	0.08	1.44	1.83
		Turmeric	0.17	2.74	4.26
		Cauliflower	0.44	8.41	25.04
		Late Wheat	0.35	1.20	3.65
		Cucurbits	0.17	2.97	8.31

*EFYEY- Elephant foot yam equivalent yield

significantly boosts regular farm output. Introducing tubers into diversified cropping systems, along with recent technological advances in markedly improves farm economics and livelihood security, while also considering ecological benefits (Suja et al., 2018). The high demand and pricing for non-conventional tuber vegetables ensure a consistent income boost for marginal farmers. Moreover, the year-round income from vegetable production facilitates the timely purchase of essential inputs like seeds and fertilizers, especially in scenarios where income is typically seasonal. The positive impact of adopting vegetable and tuber crop diversification on sustaining agriculture and enhancing livelihoods in small farms across developing countries has been widely recognized by researchers (Nedunchezhiyan et al., 2022).

The annual man days' involvement increased by over two times due to year-round cultivation of the horticultural system compared to the traditional maize-wheat system. This is because the horticultural system requires more labour for harvesting tuber crops and picking various vegetables, leading to increased employment. Additionally, this shift has reduced the trend of farm households moving to non-farm sectors for better livelihoods, contributing to income generation, employment, and poverty reduction. The studied cropping system has shown the highest per day profitability, sustainability livelihood index, and employment generation due to efficient use of farm resources.

Table 5. Agronomic productivity (t ha^{-1}), Elephant foot yam equivalent yields (t ha^{-1}) and production efficiency (kg ha^{-1} day^{-1}) of different cropping systems under cropping systems involving tuber crops

Cropping System	Agronomic productivity of crops (kg ha^{-1})			Elephant foot yam equivalent yield (t ha^{-1})			SEFYP (kg ha^{-1})	PE (kg ha^{-1} day^{-1})
	Rainy season	Winter season	Summer season	Rainy season	Winter season	Summer season		
Maize-Wheat	4.36	4.27	-	12.60	14.74	-	27337	74.89
Elephant foot yam + Greater Yam + Taro + Ginger + Turmeric +Maize-Cauliflower +Late wheat +Cucurbits	11.49	12.35	2.97	17.78	32.95	8.31	59074	161.84

having system livelihood index (0.54), with higher employment generation opportunities (162 mandays year^{-1}).

The integration of different enterprises in a system mode has been reported to increase productivity and economics, along with enhanced resource-use efficiency for marginal land holding (Suja et al., 2023). Vegetable-based crop diversification, especially with tuber crops, not only stabilizes farmers' incomes by addressing climate change risks and building resilience but also

Conclusion

Diversification through cropping systems involving tuber crops has great potential for improving farmers' livelihoods in Himachal Pradesh. Our study confirmed that integrating different crops under the system led to increased yields, efficiency, and farm income. By combining various farming activities, the system can

Table 6. System net returns, benefit cost ratio, profitability, system livelihood index (%) and employment generation (man-days) of cropping system modules

Cropping System	Gross returns	Cost of Cultivation	System Net Returns (₹)	Benefit cost ratio	System Profitability (Rs ha^{-1} day^{-1})	System Livelihood Index	Employment Generation (Mandays)
Maize-Wheat	168544	102029	66515	1.65	182	-0.34	89
Elephant foot yam + Greater yam + Taro + Ginger + Turmeric + Maize-Caulifler + Late wheat + Cucurbits	1193633	465463	728170	2.56	1995	0.54	237

ensure higher productivity, income, and year-round employment for small and marginal farmers of Himachal Pradesh. However, it is important to adjust these cropping modules with other parts of the integrated farming system to make it more sustainable and suited to the needs of different areas.

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