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Original Research Article

Analysis of growth, biomass, productivity and nutrient status in "Vigna Mungo" and "Triticum Aestivum" grown in an agroforestry system in Solan District, Himachal Pradesh, India

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ABSTRACT
The current study examined Vigna mungo and Triticum aestivum growing in a traditional agroforestry system in Solan (HP) to determine their growth, biomass, productivity, and nutrient status. Vigna mungo produced 13.63 Mg/ha of grain, 7.87 Mg/ha of straw, and a harvest index of 63.93%, whereas Triticum aestivum produced 25.40 Mg/ha of grain, 23.50 Mg/ha of straw, and a harvest index of 51.84% during the course of the two research years. In Vigna mungo and Triticum aestivum, the total biomass was found to be 33.34 Mg/ha and 74.63 Mg/ha, respectively. Additionally, the distribution of organic C, N, P, and K at soil depths of 0–15, 15–30, and 30–60 cm was examined. The physico-chemical characteristics of the soil showed that in Vigna mungo and Triticum aestivum, respectively, the pH increased from 7.77 to 8.02 and 7.60 to 7.87, and the electric conductivity reduced from 0.22 to 0.15 and 1.18 to 1.06. Additionally, the bulk density dropped from top to bottom. In Vigna mungo and Triticum aestivum, respectively, organic carbon showed a depth-wise decline from 0.73 to 0.51 and 0.60 to 0.47, as well as the same trend of decrease in potassium from 51.65 to 39.84 and 91.18 to 54.02. Nitrogen increased depth-wise. In Triticum aestivum, phosphorus increased from 0.21 to 0.31, but Vigna mungo showed the opposite tendency.

1. Introduction

In the sub-temperate mid-hills of Himachal Pradesh, India, agroforestry is a distinctive and widespread practise. Farmers sometimes practise agrihortisilviculture, which involves growing agricultural crops alongside horticulture and forest trees. Farmer output is consistent and improved when agrihortisilviculture (agricultural crops + horticulture trees + forest trees) systems are organised on the same plot of land. It is important to note that in hilly areas, life would be difficult without agroforestry because trees not only provide additional food, fuel, fibre, and fruits and vegetables, but they also slow down land slide in fields, protect crops from bad weather and wind, retain moisture, and enhance soil quality by fixing nitrogen and adding organic matter through leaf fall. Agrihortisilviculture, agrisilviculture, and agrihorticulture are common indigenous agroforestry systems in the Himalayan region, with Himachal Pradesh and Uttarakhand being the most well-known examples [1]. Three agroforestry systems—Singh et al. [2], Dadhwal et al. [3], and Toky et al. [4]—have been acknowledged for their numerous advantages. According to the IPCC, agroforestry has a great potential for carbon sequestration as part of initiatives to combat climate change [5]. It can boost agricultural production, stabilise them, and stop soil erosion [6]. In the western Himalaya, three different traditional agroforestry systems known as agrisilviculture, agrihorticulture, and agrihortisilvicultural are frequently used. Rana et al. [7] reported the species composition, biomass, and production patterns of these systems. Agrihortisilvicultural, one of the three systems, had the most varied vegetation, combining as many as 13 trees with 5 different agricultural products. Up to 25.8 t ha-1 yr-1, this system had the maximum productivity, with 68 percent of that coming from trees and the rest from annuals. The least productive agrisilviculture system, with an annual plant composition of mostly, had a productivity of 20.4 t ha-1 yr-1, with trees contributing only 27% of the total.

Regarding the ecosystem's nutrient budgeting, the distribution of nutrients in the soil and vegetation compartments is instructive [8–10]. The development of effective nutrient management methods for maximising biomass output depends on an understanding of the processes through which nutrients accumulate and are stored. It is essential to regulate the soil's organic C and nutrient pools since doing so affects not only the production of the plant but also its survival and growth. The amount of carbon that accumulates in a given climate depends on the organic matter in the soil and the availability of nutrients, which in turn depends on the manner and function of their cycling [11]. The current study aims to investigate the productivity and nutrient dynamics of agricultural crops in the current agrihortisilviculture system in Himachal Pradesh's sub-temperate mid-hills.

2. Materials and methods

In the sub-temperate midhills of Himachal Pradesh, the current inquiry on growth, biomass, productivity, and nutrient distribution was conducted during the years 2010–2011, and 2011–2012. The study was conducted in the Himachal Pradeshi district of Solan, which is located between latitudes of 300 50'30" and 300 52'0" N and longitudes of 770 8'30" and 770 11'30" E. It belongs to the mid hills, sub-temperate, Zone-II classification. Shoolini University was chosen as the study site, which is about 4 km away. From the study site, samples of agricultural crops were randomly chosen.

Study Site

The community of Sultanpur, where agroforestry practises are traditionally practised, was chosen as the study site for the current research. It is a mixed production system that incorporates both forest and agricultural crops. The prominent tree species, crops, vegetables and fruits grown in the study area are: Grewia optiva Drumm. (Beul), Bauhinia variegata Linn. (Kachnar), Celtis australis Linn. (Khirak) and Toona ciliata Roxb. (Toon), Triticum vulgaris (Wheat), Brassica compestris (Sarson), Lycopersicon esculentum (Tomato), Capsicum annuum (Shimla - mirch), Zea mays (Maize), Vigna mungo (Black gramme), Pisum sativum (Pea), Pyrus communis Linn. (Nashpati) and Punica granatum Linn. (Daru). The terraced agricultural fields have trees growing along the edges, although not in a set pattern.

Growth, Biomass and Yield Attributes of Vigna mungo and Triticum aestivum

In the agroforestry area, five 50x50 cm quadrates were put out in triplicate. When the crops in the laid quadrates reached maturity, they were collected and divided into grain (seeds) and straw (vegetative part, which includes shoots and leaves). We measured the height of the crop, the crop density, the number of leaves per plant, the number of pods or spikes per plant, and the number of grains per plant. Crop weight, both fresh and dried, was also measured to estimate biomass. The crops were taken from the sample plots (50 × 50 cm) when they reached maturity. The seeds were manually threshed, cleaned, and weighed. Per plant, the number of grains was counted. Finally, the typical grain and straw yields were identified. Khandakar [12] provided the formula for calculating harvest index (HI):

$$\text{Harvest index} = \frac{\text{Grain yield}}{\text{Biological yield (grain + straw)}} \times 100$$

According to the set of procedures used at the Dr. Y. S. Parmar University of Horticulture, Solan, the cultural operations carried out on Vigna mungo and Triticum aestivum were [13].

Soil Nutrient Analysis

Random soil samples were taken from the study location at depths of 0–15 cm, 15–30 cm, and 30–60 cm. The distribution of nutritional elements and other parameters were examined in samples from five replications of each soil depth at the study location. Prior to measurement of physical and chemical parameters, collected soil samples were dried, pulverised with a mortar and pestle, and sieved through a 2 mm filter. Analysis of the pH, electric conductivity, bulk density, percentage of organic carbon, and accessible N, P, and K levels in the soil at various depths of the chosen location. According to Jackson's method [14], pH and electric conductivity were measured, and Singh's specific gravity bottle method [2] was used to assess bulk density. The Walkley-Black Method was used to analyse the organic carbon [15]. The Micro-Kjheldhal technique described by Chapmann and Pratt [16] was used to determine nitrogen. By using a flame photometer [17] and a spectrophotometric technique [18], potassium and phosphorus were examined, respectively.

3. Results and discussion

Table 1 lists the growth and yield characteristics of Vigna mungo and Triticum aestivum. It is clear that Vigna mungo plants grow the same height whether they are part of a tree system or grown alone, however Triticum aestivum plants grow differently and grow significantly better without a tree system. No statistically significant difference in crop density between two crops grown in an agroforestry system or as the only crop was discovered. The presence and absence of trees caused a large variance in grain production, number of pods, and number of grains. The production of a single crop of Vigna mungo was over 1.76 times higher than that of a crop grown in a tree system, but it was only 1.28 times higher for Triticum aestivum. It should be noted that there was significant difference in the Harvest Index between two crops grown in an agroforestry system or alone. In Vigna mungo and Triticum aestivum, the total biomass was found to be 33.34 Mg/ha and 74.63 Mg/ha, respectively (Table 2). Leaf, shoot, root, and pod provided 29,06%, 41.57%, 4.94%, and 24.35%, respectively, to the total biomass of Vigna mungo. Similar to this, the leaf, stalk, root, and spikes of Triticum aestivum provided 20.91%, 28.94%, 18.98%, and 31.16% of the total biomass.

According to the physico-chemical characteristics of soil in Vigna mungo and Triticum aestivum planted in an agroforestry system at depths of 0–15, 15–30, and 30–60 cm, soil pH increased from top to bottom while electric conductivity and bulk density declined. In Vigna mungo, organic carbon, phosphorus, and potassium all decreased, although nitrogen exhibited a trend in the other direction. Electric conductivity reduced from 0.22 to 0.15 and 1.18 to 1.06 in Vigna mungo and Triticum aestivum, respectively, whereas pH increased from 7.77 to 8.02 and 7.60 to 7.87. Bulk density in Vigna mungo and Triticum aestivum, respectively, fell from 1.13 to 1.07 and 0.61 to 0.51 from top to bottom. In Vigna mungo and Triticum aestivum, respectively, organic carbon and potassium showed a depth-wise drop from 0.73 to 0.51 and 0.60 to 0.47, and potassium from 51.65 to 39.84 and 91.18 to 54.02. In Triticum aestivum and Vigna mungo, respectively, nitrogen levels increased depth-wise from 262.73 to 311.97 and from 329.59 to 383.29, respectively. In Triticum aestivum, phosphorus likewise increased from 0.21 to 0.31, whereas Vigna mungo showed the opposite tendency, as seen in Figures 1–7.

Table 1: Triticum aestivum and Vigna mungo growth and yield characteristics in an agroforestry system

Parameters	Vigna mungo		Triticum aestivum	
	78.20±5.12	79.08±4.88	41.00±1.04	51.00±1.55
Plant height (cm)	11.39±0.48	12.42±0.50	23.90±0.20	26.80±1.30
Crop density (m^{-1})	14.79±0.19	14.12±0.20	44.48±1.20	51.30±1.55
No. of leaves/plant	11.02±1.33	12.22±0.67	6.60±0.10	6.01±0.20
No. of pods/spikes/plant	70.20±1.98	110.30±2.72	48.70±0.55	51.10±0.15
No. of grains/plant	14.04±0.76	24.08±1.22	26.50±0.60	31.98±0.80
Grain yield (Mg/ha)	8.98±1.65	12.60±0.99	24.85±1.50	29.05±1.15
Straw yield (Mg/ha)	70.78±2.22	65.10±0.60	52.20±0.2	53.50±0.80

Table 2: Triticum aestivum and Vigna mungo's biomass characteristics in an agroforestry system

Biomass (Mg/ha)	Vigna mungo		Triticum aestivum	
	With tree	Without tree	With tree	Without tree
Leaf	9.69±0.75	12.32±1.58	15.61±4.93	13.98±1.22
Shoot	11.86±3.08	12.00±2.60	21.6±6.90	23.56±2.44
Root	1.65±0.017	1.25±0.15	14.17±3.29	13.08±2.52
Pod/Spikes	8.12±0.22	12.62±0.98	23.26±1.55	28.63±2.00
Total	33.34±2.10	38.19±0.11	74.63±13.57	79.25±4.18

Different researchers from coconut-growing regions have demonstrated the influence of agroforestry systems on soil fertility in terms of higher organic matter content, total nitrogen, accessible phosphate and potash in the top soil, and improved microbial activity in the system [19–23]. In the tarai tract of the Kumaon hills, Singh et al. [2] studied the amount of litter fall, its chemical composition, the addition of nutrients, and changes in the chemical composition of the soil under agroforestry systems involving Populus deltoides and Eucalyptus hybrid trees with intercrops of aromatic grasses Cymbopogon martini and C. flexuosus. In comparison to Eucalyptus hybrid, Populus deltoides produced 5 kg of dry litter per tree per year on average. Under the canopies of these two trees, accessible nitrogen increased by 38.1 to 68.9 percent over control in the 0–15 cm soil layer, while soil organic carbon increased by 33 to 38 percent. Under Populus deltoides, fertility levels increased substantially more than under Eucalyptus hybrid.

The availability of nutrients, which in turn depends on the manner and function of their cycling, has an impact on the productivity (biomass) of trees. The development of nutrient management methods for maximising biomass output benefits from an understanding of nutrient accumulation and storage mechanisms. The growth, biomass, carbon storage, and fluctuations in the nutrients (N, P, and K) in 1 to 6 year old chronosequence plantations of Gmelia arborea have previously been examined by Swamy et al. [24]. Within 6 years, the amount of soil organic carbon increased from 8.46 to 14.02 Mg ha-1. Available N increased by 14.85%, 11.98%, and 11.25% at soil levels of 0–20 cm, 21–40 cm, and 41–60 cm, respectively. Available K increased by 10%, 9.13%, and 10.63%, whereas P decreased by 26%, 23%, and 20%. Lal [25] also noted changes in the level of nutrients and soil organic carbon under various management techniques. He discovered that, compared to regular arable crops, alley cropping of Leucaena and Gliricidia significantly reduced the relative rates of loss in the status of nitrogen and organic carbon over a period of six years (12 cropping seasons).

Under a six-year-old P.deltoides plantation, Kohli et al. [26] assessed the performance of seven winter-season crops, including Triticum aestivum, Cicer arietinum, Lens culinaris, Avena sativa, Trifolium alerandrum, Brassica compestris, and Pisum sativum. When compared to solely crops (without trees), P.deltoides plantations dramatically reduced crop germination, plant height, biomass, and relative growth rate. Similar to this, Burgess et al. [27] assessed the productivity of four poplar hybrids (Beaupre, Trichobel, Robust, Gibecq) planted at 10m x 6.4m in three distinct low land sites in England. These hybrids were Beaupre, Trichobel, Robust, and Gibecq. Across three sites, the yield per unit of planted area was on average 4% lower in the first three years and on average 10% lower between years four and six when compared to the crop yield in the control regions. Wheat (Triticum aestivum), barley (Hordeum vulgare), and mustard (Brassica alba) benefited from fallow more than other cereal crops in terms of yields, but field beans (Vicia Faba), peas (Pisum sativum), and mustard (Brassica alba) did not. In comparison to solitary crops, all of these crops produced higher yields in their first year when grown under poplar clones.

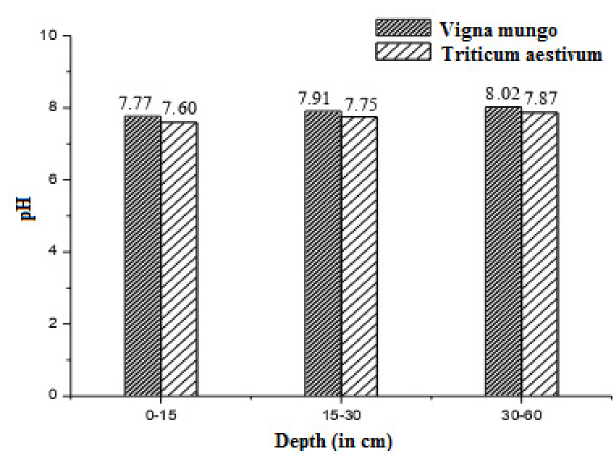

Figure 1: pH at Different Soil Depths

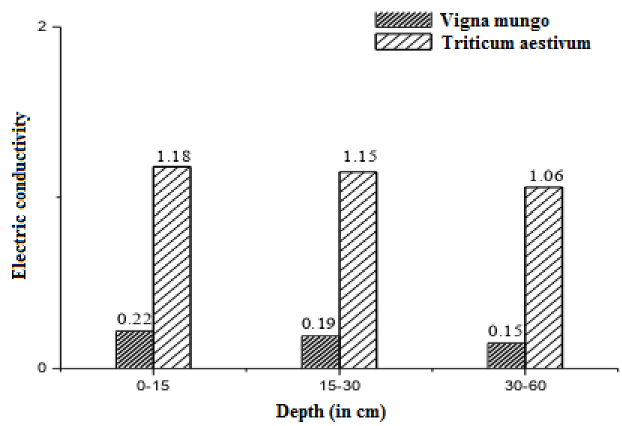

Figure 2: Electric Conductivity at Different Soil Depths

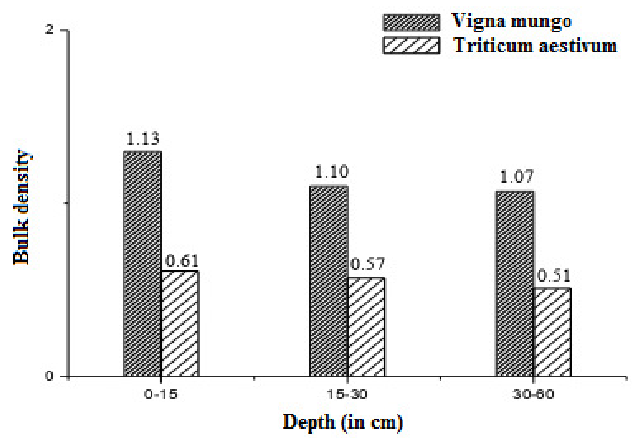

Figure 3: Bulk Density at Different Soil Depths

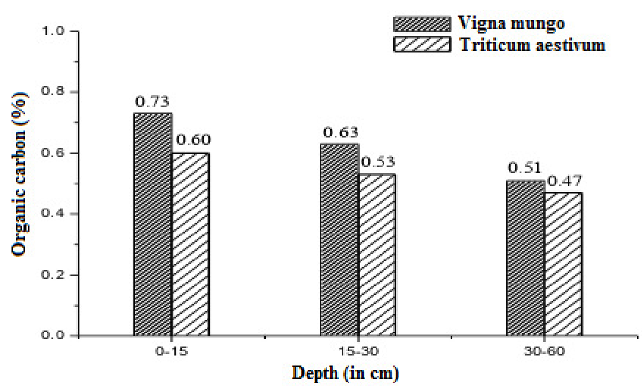

Figure 4: % Organic Carbon at Different Soil Depths

Also reported by Swamy and Puri [28] was the crop productivity in the agrisilviculture system. The greatest drop in grain output under 5-year-old G. arborea stands was in urd (65%), followed by mung bean (59%) and cowpea (34%) during the rainy season. The lowest yield losses were seen in soybean (5-year-old stands: 25% grain yield loss and 26% straw yield loss). In comparison to soybean, yield losses from mung and urd crops were more than twice as high for both straw and seed. The drop in grain output under G. arborea stands that were five years old was in the following order: chickpea (36%) > linseed (16%) > mustard (14%) > wheat (7%). Similarly, chickpea (20%), mustard (9%), linseed (6%) and wheat (4%), in that order, had the greatest decline in straw output. The grain and straw yields of chickpea decreased by five times as much as those of wheat in G. arborea stands that were five years old. It is important to note that productivity in Vigna mungo was nearly 1.76 times higher in a solo crop compared to a crop growing under a tree system; however, this variance was relatively less in Triticum aestivum and was 1.28 times higher in a sole crop.

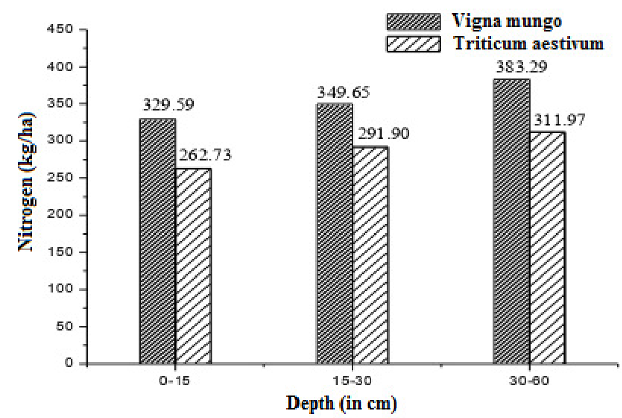

Figure 5: Amount of Nitrogen at Different Soil Depths

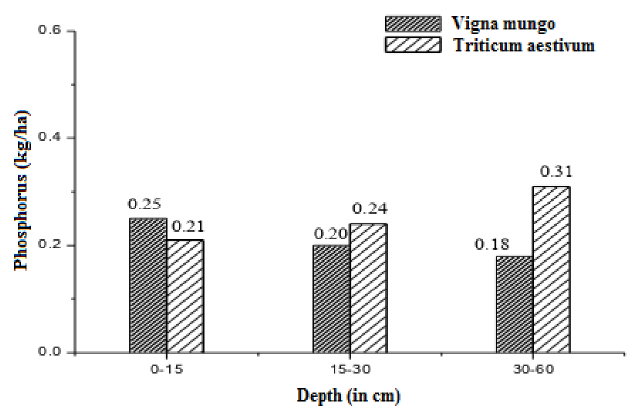

Figure 6: Amount of Phosphorus at Different Soil Depths

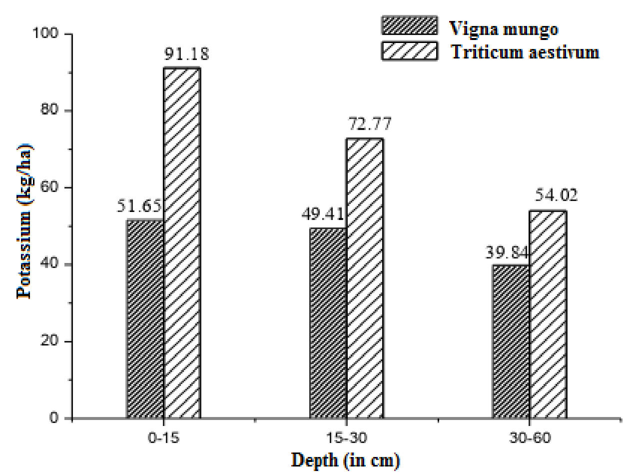

Figure 7: Amount of Potassium at Different Soil Depths

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