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Evaluation of growth and production behaviour of *Brassica campestris* L. under an existing agroforestry system in mid hills of Himachal Pradesh

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Abstract
The current study was aimed to examine the growth, biomass and productivity of *Brassica campestris* L. grown in a traditional agro forestry system in the district Solan of Himachal Pradesh. A traditional agro-forestry system includes trees as well as crops and vegetables. *Toona ciliata*, *Bauhinia variegata* and *Grewia optiva* were among the tree species present. Plant height, crop density, number of leaves, number of silique, number of grains, grain yield, straw yield and harvest index were investigated during both the years of study. Average plant height, number of leaves, and number of grains ranged from 35.03 to 38.53 cm, 37.32 to 43.13 cm, and 265.52 to 285.46, respectively. Sole crop (control) had the highest grain yield (13.81 Mg/ha), straw yield (9.04 Mg/ha) and highest harvest index (62.48%) during first year of study. Site S3 had the highest grain (15.82 Mg/ha) and straw (9.44 Mg/ha) yields in the second year while Site S1 has the highest harvest index (62.95%). The presence of trees clearly influenced the amount of grains per plant, as it reduced when compared to the sole crop in the first year. Biomass varied from 8.29 to 11.97 Mg/ha, 18.42 to 24.88 Mg/ha, 4.31 to 5.16 Mg/ha and 8.43 to 9.16 Mg/ha in leaf, shoot, root and silique, respectively, during two years of study. The examined control site and the other four sites had statistically significant biomass differences. Growth parameters, grain yield and straw yield varied with distance from the tree base. Further the lower crop yield and harvest index of crop under tree can be due to the shade effects as well as competition of roots for moisture and nutrients. It could be managed by the regular pruning of branches of trees present in the existing agroforestry systems in hilly areas that has multiple benefits to the rural community.

Keywords: Agro forestry, biomass, growth, straw yield, grain yield, harvest index and productivity

Introduction

Agro forestry is a unique and widely used practise in Himachal Pradesh's mid-hill Himalayan area. Trees have been identified with several locations on this region's agricultural fields. Farmers intentionally improve the tree species to meet their demands for fuel, fibre, fodder, fruits, and lumber, among other things, in addition to agricultural products. Agro forestry is described as "intensive land use management that maximises the benefits of biophysical interactions created when trees and/or shrubs are intentionally combined with crops or livestock" (Gold *et al*., 2000) [11]. All land users benefit from increased social, economic, and environmental benefits as well as a more diverse and sustainable agricultural system (Sanchez, 1995; Fay, 1998 and Leakey, 1996) [31, 9, 22].

According to Makundi and Sathaye (2004) [23], planting trees alongside crops enhances soil fertility, regulates and prevents soil erosion, regulates water logging, boosts local biodiversity, lessens the demand for fuel from natural forests, and feeds cattle with food. The growth of understory crops depends heavily on tree design. Crown distribution affects crop performance and yield potential in addition to the microsite environment and soil characteristics. According to research reports (Gillespie *et al*., 2000; Kessler, 1992; Lakshmma and Rao, 1996; Ong *et al*., 1991; Puri and Bhargwa, 1992 and Rao *et al*., 1998) [10, 17, 21, 25, 28, 30], tree canopies have an impact on how well under storey vegetation performs. There is a distinct interaction between the components, which may be complementary/facilitative or competitive, due to the variations in development patterns and resource requirements of trees and agricultural components.

Brassica campestris L. is a herbaceous plant with an upright, branching stem up to 1.0 m tall and a taproot 60-80 cm deep. Lower leaves are petioled and green, with a white bloom on occasion. The blooms are made up of four (four) yellow petals grouped cruciformly and tetradynamous stamens with yellow anthers. Seeds are planted in very early spring. To minimise the breaking, plants are often plucked before the fruits are fully mature. Depending on the variety and climatic circumstances, the growth period ranges from 40 to 60 days. Indian mustard is a cool-season crop that thrives in temperatures between 15 and 18^{0}C. Mustards thrive best in chilly growing conditions.

According to research findings, contemporary agro forestry systems may be both ecologically beneficial and economically viable. Tree crop interaction research is critical for developing appropriate agro forestry models in mountainous regions such as Himachal and Uttarakhand. Although there have been a lot of research on Himalayan agro forestry systems (Ralhan *et al*., 1991; Sundriyal *et al*., 1994; and Toky *et al*., 1989) [29, 33, 34], the productivity of agricultural crops under agro forestry systems has not been thoroughly calculated. Agroforestry systems are designed for the beneficial interactions of crop plants, to reduce the unfavourable interactions, to minimize the risks associated with agriculture and also to increase the sustainability of agriculture. Timber plantations can enhance the benefits from global environmental facilities (Dogra, 2007 and Pandey, 2007) [8, 27]. So there is a great need to identify the suitable agricultural and horticultural crops that can be grown well along with the limited solar energy available underneath the trees (Nayak *et al*., 2014) [36].

Keeping this in mind, the current study is an attempt to investigate the productivity of *Brassica campestris* L. in an established agrisilviculture system in Himachal's subtropical mid highlands. As a result, the current study was proposed to investigate the growth and yield characteristics of *Brassica campestris* L. in an agro-forestry system, as well as to evaluate the biomass and productivity of agriculture crop.

Materials and Methods

Study Site

The district of Solan in Himachal Pradesh is where the current study was carried out (Fig.1), which is located between 30^0 50'30"-30^0 52'0" N latitudes and 77^0 8'30"-77^{0}11'30" E longitude (Survey of India Top sheet No. 53F/1) during the year 2019 and 2020. It is classed as Zone II, sub-temperate and sub-humid, mid hills, with primarily sub-alpine Chir-pine flora. Traditional agro forestry lands are dominated by beautiful green natural flora. The study site is close to Shoolini University, which is located 4 km away. Agro-silviculture practises are used in Sultanpur, which is a combined production method that includes both agricultural crops and forest. *Bauhinia variegata* Linn. (Kachnar), *Grewia optiva* Drumm. (Beul), and *Toona ciliata* Roxb. (Toon) were the most prominent tree species in the study region. The agricultural fields had terraces, and trees grew in a random pattern along the boundaries. The soil type is inceptisols and the texture is gravelly, sandy, and loamy (Devi *et al*., 2013). Figure 2 shows the Google map of the research site.

Growth, biomass and yield attributes of *Brassica campestris*

Five 50x50 cm quadrates in triplicates were randomly placed for the assessment of the growth and biomass of *Brassica campestris* L. site 1 (control), site 2, site 3, site 4, and site 5. Agricultural crop samples were collected from farmers' farms in a totally randomised design. *Brassica compestris* L. samples from the laid quadrates were gathered at the maturity stage from both the control and crop growing under trees. Crop height, crop density, cob number per plant, leaf number per plant, and grain number per plant were measured. The mature crop was then sorted into grains and straw and dried to calculate the net yield of *Brassica campestris* L. To indicate the percentage of a plant's economically useful output in relation to its productivity, the Harvest index is calculated using the following formula (Khandakar, 1985) [18].

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

Fresh and dry weights were also measured for biomass estimate of the crop. *Brassica campestris* L. was subjected to cultural operations in accordance with the practises implemented at Dr. Y. S. Parmar University of Horticulture, Solan (Anon, 2006) [1]. Data from all parameters (growth, biomass, and productivity) were statistically using Duncan's multiple range test (DMRT), tested at $p<0.05$

Fig 1: Location map of Solan district, Himachal Pradesh

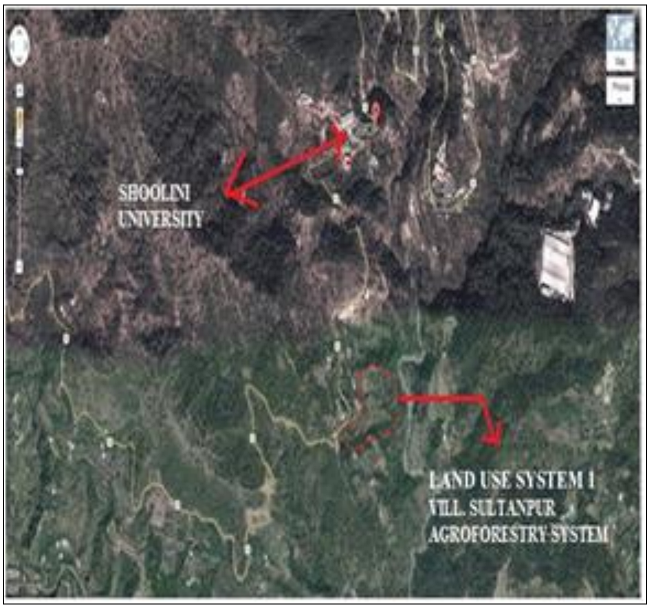

Fig 2: Google map showing study site

Results and Discussion

The morphological features of *Brassica campestris* L. cultivated as a sole crop and along with trees are given in Table 2. Plant height varied from 26.9 to 50.9 cm during the first year and from 26.8 to 43.9 cm in the following year. It was greatest in a single crop and lowest in all other places where crop was grown alongside the trees. The number of leaves was higher in plants growing beside trees in general. From the first to the second year of research, the average plant height, number of leaves and number of grains ranged from 35.03 to 38.53 cm, 37.32 to 43.13, and 265.52 to 285.46, respectively. During the year 2019, site S1 had the highest grain production (13.81 Mg/ha), site S4 had the highest straw output (9.04 Mg/ha), and site S2 had the highest harvest index (62.48%). Site S3 had the highest grain (15.82 Mg/ha) and straw (9.44 Mg/ha) yields in the year 2020. Site S1 has the highest harvest index (62.95%). Results are comparable with other researchers such as Kanwal *et al*., (2019) [15].

According to research by Boscae and Gallagher (1977) [5], the rate of biomass formation in many crops is related to the radiation intercepted, less translocation of photosynthates from source to sink, and competition for nutrients and water (Mathur *et al*., 2000; Sibbal *et al*., 2001; Yakadri *et al*., 2002; Anbumani *et al*., 2003 and Pandey, 2004) [24, 32, 35, 2, 26]. It is evident from Table 2 that the presence of trees had an effect on the quantity of grains per plant and harvest index, which dropped when compared to the sole crop during both the study years.

Leaf, shoot, root, and silique biomass of *Brassica campestris* L. is given in Table 1. Biomass of different plant components was as follows: shoot>silique>leaf>root. Biomass ranged from 8.29 to 11.97 Mg/ha, 18.42 to 24.88 Mg/ha, 4.31 to 5.16 Mg/ha, and 8.43 to 9.16 Mg/ha in leaf, shoot, root, and silique, respectively from the year 2019 to 2020. It showed a statistically significant difference in the biomass among the examined control site and the other four sites. Fig. 1 shows that mean leaf biomass of *B. campestris* as intercrop was maximum in S1 (10.7 Mg/ha) and minimum in site S5 (8.6 Mg/ha). Mean shoot and root biomass was found to be maximum in control site (S1) 44.0 Mg/ha and 6.5 Mg/ha respectively and minimum in S4 (14.5 Mg/ha) and S5 (2.8 Mg/ha). Similar to other silique biomass was found highest in S1 (9.2 Mg/ha). Results of present study were in accordance with studies reported earlier by Bijalwan, 2011; Kaur and Puri 2013; Kaur *et al*., 2016; Kaur *et al*., 2017 [4, 12, 13, 14].

Brassica campestris L. cultivated as a solitary crop and with trees demonstrated that plant growth and production were greater in sole crop locations than in sites where crop and trees were grown together. As previously noted, plausible explanations include a lack of light and competition for belowground resources such as water and nutrients (Bhardwaj and Gupta, 1993; Kushwaha and Mathur, 1995; Kohli *et al*. 1996; Kaur and Puri., 2013; Kaur *et al*., 2016; Kaur *et al*., 2017; and Kanwal *et al*., 2022) [3, 20, 19, 12, 13, 14, 16]. Choudhary *et al*., (2022) [6] also reported that for achieving better crop productivity and profitability in B. *campestris*, it is better to go with integrated nutrient management practices over sole use of chemical fertilizers. As it will also help to maintain the environmental quality as well as in achieving sustainability in agriculture.

Table 1: Biomass attributes of *Brassica campestris* L. grown under agro forestry during two years of study (2019 and 2020)

Site	Leaf biomass (Mg/ha)			Shoot biomass (Mg/ha)			Root biomass (Mg/ha)			Silique biomass (Mg/ha)		
	1st year	2nd year	Mean	1st year	2nd year	Mean	1st year	2nd year	Mean	1st year	2nd year	Mean
S1	6.1 c	15.4 a	10.7	48.4 a	39.6 a	44.0	6.6 a	6.5 b	6.5	9.0 a	9.4 a	9.2
S2	9.5 a	11.8 b	10.4	27.7 b	25.6 b	26.6	5.2 b	6.0 c	5.6	8.2 ab	8.7 c	8.4
S3	9.5 a	10.7 ab	10.1	11.1 e	18.8 b	14.9	4.9 b	6.7 a	5.8	8.4 ab	8.1 d	8.2
S4	5.1 d	13.2 a	9.1	14.3 d	14.7 b	14.5	5.1 b	4.0 d	4.5	8.6 b	9.0 b	8.8
S5	8.9 b	8.4 b	8.6	20.4 c	26.4 b	23.4	1.9 c	3.8 e	2.8	7.9 b	9.3 a	8.6
Mean ± S.E.	8.29±0.96	11.97±1.34		18.42±3.26	24.88±4.90		4.31±0.70	5.16±0.65		8.43±0.20	9.16±0.14	
	10.13			21.65			4.70			8.79		

Values are Mean ± standard error.
Note S1 (Control) – Site 1 without trees, S2, S3, S4 and S5 are sites with trees
Values in the column followed by different letter (s) are significantly different (p<0.05) according to DMRT.

Table 2: Growth and yield attributes of *Brassica campestris* L. grown under agro forestry system during two years of study (2019 and 2020)

Site	Plant height (cm)		Crop density (m^{-1})		No. of leaves per plant		No. of silique per plant		No. of grains per plant		Grain yield (Mg/ha)		Straw yield (Mg/ha)		Harvest Index (%)	
	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year
S1 (control)	43.88± 0.07a	50.89± 3.86a	4.67± 0.33 a	2.67± 0.33 a	23.27± 0.93e	35.5± 2.10 c	13.79± 0.08e	20.55± 1.32a	242.14± 5.46 b	338.50± 25.88 a	13.81± 0.21a	16.4± 0.06d	8.67± 0.21ab	8.14± 0.02d	62.48± 1.50a	62.95± 0.05 a
S2	40.88± 0.04b	46.21± 6.56ab	4.33± 0.33 a	3.33± 0.33 a	35.22± 0.74d	46.12± 1.70 b	15.56± 0.12c	19.61± 0.10ab	253.99± 0. 12 b	289.79± 7.86 ab	13.71± 0.11a	14.60± 0.02c	8.26± 0.57ab	8.77± 0.03c	61.44± 0.88a	62.47± 0.06 b
S3	38.07± 0.08c	29.62± 10.32 ab	2.33± 0.33 b	3.33± 0.33 a	46.38± 0.13a	44.46± 2.56b	16.18± 0.12b	17.37± 0.62c	305.86± 26.83 a	252.86± 15.01 b	11.29± 0.10d	15.82± 0.07a	8.45± 0.07ab	9.44± 0.06a	57.19± 0.21bc	62.62± 0.04 b
S4	25.50± 0.09e	39.03± 5.70ab	2.67± 0.33b	3.00± 0.00a	39.72± 0.28c	55.76± 0.88a	15.17± 0.13d	16.57± 0.34c	249.36± 4.36b	279.94± 3.20ab	12.68± 0.08b	14.89± 0.04b	9.04± 0.14a	9.06± 0.06b	58.38± 0.53c	62.15± 0.11 c
S5	26.83± 0.04d	26.90± 1.63b	3.00± 0.00 b	3.33± 0.33 a	41.98± 0.08b	35.77± 1.56c	18.42± 0.12a	17.52± 0.06bc	276.23± 15.16 ab	266.19± 25.78 b	12.05± 0.15c	15.70± 0.08a	7.96± 0.23b	9.35± 0.08a	60.24± 0.39ab	62.66± 0.07 b
Mean ± S.E.	35.03± 0.01	38.53± 1.45	3.40± 0.07	3.13±0.07	37.32± 0.17	43.13± 1.18	15.83± 0.01	18.32± 0.23	265.52± 4.79	285.46± 4.6	12.71± 0.02	15.31± 0.19	8.48± 0.09	8.95± 0.24	59.95± 0.23	62.57± 0.13

Values are Mean ± standard error.
Note S1 (Control) – Site 1 without trees, S2, S3, S4 and S5 are sites with trees
Values in the column followed by different letter (s) are significantly different (p<0.05) according to DMRT.

Conclusion
There is no doubt that the ancient agro forestry method investigated has been in use for generations in the Himalayan mid-hills. Although the system produces lower yields than single crops, these complex agro forestry land use systems provide a diverse range of resources for household consumption such as meals, medicines, construction materials, and fuel and fodder. In the current investigation, it was discovered that growth and yield parameters reduced the most in the proximity of the tree stem. *Brassica campestris* L.'s maximum crop growth (plant height), number of silique per plant, crop density, grain yield, and harvest index were all measured under the control condition.

Future scope
For farmers, Agroforestry is source of improved income and lower risk from adverse weather conditions as the trees have high climatic resilience. It has a potential to reduce soil erosion and runoff and it maintains soil physical properties and also helps to promote the efficient nutrient cycling along with nitrogen fixation. Rapid progress in reliable modelling of trees along with crop performance for such systems are required to ensure that agro forestry systems fulfils its potential for reducing the poverty, fostering sustainability and food security. A model for simulating agro forestry has to be implemented for wide range of tree-crop designing which has more potential for the betterment of tree-crop interaction.

Author's contribution
RK- Manuscript Preparation and Statistical Analysis; KD-Manuscript Layout and Final Corrections; MC- Manuscript Preparation and Statistical Analysis; SP-Research Guidance and Manuscript Finalization.

Conflict of interest statement
Authors declare that they have no conflict of interest.

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