

PERFORMANCE OF WHEAT UNDER EUCALYPTS AND GUAVA BASED AGRI-HORTI AND AGRI-SILVI-HORTI SYSTEM IN HARYANA

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SUMMARY

Agroforestry systems offer a sustainable approach to enhancing land productivity by integrating trees with agricultural crops. A field experiment was conducted during 2019-2020 at the Forestry Research Farm, CCS Haryana Agricultural University, Hisar, Haryana to evaluate the growth of eucalypts and guava and their effects on wheat performance under different agroforestry systems. Eucalypts seedlings (clone P-23) and guava plants (var. Hisar Safeda) were transplanted at 7 m × 4 m spacing in a randomized block design. Wheat variety HD-2967 was sown during the first fortnight of November 2019 under Agri-Horti and Agri-Silvi-Horti systems. Tree growth parameters were recorded at the time of wheat sowing and after harvest of the crop. Eucalypts attained an average height of 7.43 m, basal diameter of 11.34 cm and DBH of 10.96 cm at the time of wheat harvest. Guava showed slightly higher height under agri-horti system (1.10 m) compared to agri-silvi-horti system (1.05 m). Wheat plant height and yield attributes were comparatively higher in the sole crop than in agroforestry systems. Maximum grain yield (5.05 t/ha) was recorded under sole wheat, while among agroforestry systems the highest grain yield (4.81 t/ha) was recorded in the guava-based agri-horti system. The results indicated that wheat can be effectively cultivated under tree-based systems with moderate yield reductions, while providing additional economic and ecological benefits through tree components.

Key words: Agroforestry, *Eucalyptus tereticornis*, *Psidium guajava*, wheat and Agri-Horti system

Agroforestry has emerged as a sustainable land-use system that integrates trees, crops and sometimes livestock on the same land management unit to enhance productivity, environmental sustainability and economic returns. The system improves soil fertility, enhances biodiversity, and provides diversified income sources to farmers while maintaining ecological balance. In recent years, agroforestry has gained considerable attention in India due to increasing pressure on agricultural land, declining soil health and the need for climate-resilient farming systems (Kumar *et al.*, 2022). The integration of trees with agricultural crops can improve resource use efficiency, microclimate regulation and long-term sustainability of production systems.

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops in the world and serves as a staple food for a large proportion of the global population. In north-western India, particularly in Haryana, wheat is the major *Rabi* crop cultivated under irrigated conditions following the rice-wheat cropping system. The state plays a crucial role in national food security due to its high productivity and extensive adoption of improved varieties and agronomic practices. However, continuous monocropping of wheat and rice has resulted in soil degradation, declining groundwater levels and reduced sustainability of the production system. Therefore, diversification through agroforestry systems has been increasingly advocated as an alternative strategy for sustainable agricultural development.

Agroforestry systems involving tree species such as eucalypts have become widely popular among farmers in northern India. Among these, eucalypts (*Eucalyptus tereticornis*) is one of the most widely adopted tree species in agroforestry systems due to its fast growth, adaptability to different soil and climatic conditions, and high economic returns. In Haryana, eucalypts is commonly planted on field boundaries, bunds and in block plantations, often integrated with agricultural crops such as wheat, barley and mustard. The species is valued for its industrial demand, particularly in paper, pulp and timber industries, making it economically attractive for farmers. Studies have shown that eucalypts-based agroforestry systems can provide substantial economic benefits, although crop yields may sometimes decline due to competition for light, water and nutrients (Sirohi *et al.*, 2021).

In addition to timber species, fruit-based agroforestry systems have also gained importance for enhancing farm income and nutritional security. Guava (*Psidium guajava L.*) is one of the most popular fruit crops in India due to its high adaptability, nutritional value and economic potential. It is widely cultivated in tropical and subtropical regions and can be successfully integrated with agricultural crops during the initial years of orchard establishment. Guava-based agri-horticultural systems allow farmers to obtain income from intercrops while the fruit trees are still immature, thereby improving overall land productivity and profitability. Moreover, guava trees have relatively moderate canopy architecture compared to timber species, which may allow better light penetration and reduce competition with understory crops.

Agroforestry systems combining timber trees and fruit crops with agricultural crops, such as agri-silvi-horticultural systems, are increasingly being explored as a means of maximizing land productivity and resource use efficiency. In such systems, timber trees provide long-term economic returns, fruit trees contribute regular income and nutritional benefits, while annual crops provide short-term food and income security. The integration of multiple components enhances system resilience and reduces economic risks associated with monocropping. Fast-growing tree species like eucalypts have been shown to provide additional ecosystem services, including carbon sequestration, microclimate regulation and improved soil properties when integrated with agricultural crops (Jain and Mehta, 2023).

Several studies have evaluated the performance of wheat under different agroforestry systems in northern India. Studies on crop

productivity under different agroforestry systems have indicated that yields of intercrops may decrease under tree shade compared with open conditions, although the overall system productivity and profitability often remain higher due to the additional output from tree components (Sharma *et al.*, 2025). In Haryana, agroforestry practices involving eucalypts and other multipurpose tree species have become an integral part of farming systems. Farmers often cultivate agricultural crops in the interspaces between tree rows, especially during the early years of plantation. Research has indicated that careful selection of crop species and varieties, along with appropriate tree spacing and management practices, can minimize competition and improve crop performance under tree-based systems. The success of agroforestry systems largely depends on the compatibility between tree and crop components, efficient resource sharing and proper management of tree canopy and root systems.

Despite the increasing adoption of agroforestry systems in Haryana, information on the performance of wheat under integrated systems involving eucalyptus and fruit crops such as guava is still limited. Most previous studies have focused on single tree-crop combinations, whereas integrated systems involving timber trees, fruit crops and annual crops have not been adequately explored. Evaluating crop performance under such systems is essential for understanding resource interactions and identifying suitable combinations that can maximize productivity and sustainability. Therefore, the present study was undertaken to assess the growth and yield performance of wheat under different tree-based systems and compare them with open field conditions.

MATERIALS AND METHODS

The present study was conducted at research area of the Department of Forestry, CCS Haryana Agricultural University, Hisar (29° 10' N lat., 75° 46' E long., alt. 215 m msl). In this study, eucalypts seedlings (clone P-23) and guava plants (var. Hisar Safeda) were transplanted during July-August 2019 at a spacing of 7 × 4 m following a randomized block design. During *Rabi* season wheat variety HD-2967 was sown during the first fortnight of November 2019 under agri-horti and agri-silvi-horti systems. The standard package of practices as recommended by CCS HAU, Hisar was followed. The growth, yield attributes and yield of wheat crop were recorded during the study period.

RESULTS AND DISCUSSION

Tree growth performance of Eucalypts and Guava

The growth performance of eucalypts (clone P-23) and guava (var. Hisar Safeda) under different agroforestry systems during the wheat growing season (November 2019-April 2020) is presented in Table 1. The results indicated a considerable increase in growth parameters of both tree species during the experimental period.

Growth of Eucalypts

In agri-silvi-horti system (Eucalypts + Guava + Wheat), eucalypts exhibited significant improvement in all growth parameters from sowing to harvesting of wheat crop. The average tree height increased from 4.99 m in November 2019 to 7.43 m in April 2020, recording a height increment of 2.44 m (48.9%) during the cropping period. Similarly, the basal diameter increased from 7.25 cm to 11.34 cm, while diameter at breast height (DBH) increased from 6.81 cm to 10.96 cm. The substantial increase in height and diameter of eucalypts suggests that the tree component maintained vigorous growth even under the intercropping system with wheat and guava. The rapid growth of eucalypts may be attributed to its fast-growing nature and efficient utilization of available resources such as soil moisture, nutrients and solar radiation. Since the trees were relatively young during the experimental period, the competition with understory crops was minimal, allowing satisfactory growth of both tree and crop components. Similar results were reported in eucalypts-based agroforestry systems where tree growth parameters increased significantly over time due to efficient utilization of site resources and improved microclimatic conditions created by mixed cropping systems. Studies have shown that eucalypts trees maintain rapid growth even when integrated with agricultural crops in agroforestry

systems (Tripathi *et al.*, 2020). Agroforestry systems involving eucalypts have also been reported to improve system productivity and resource use efficiency (Ramesh *et al.*, 2023).

Growth of Guava

The growth of guava plants differed slightly between the two agroforestry systems. In the agri-silvi-horti system (Eucalypts + Guava + Wheat), guava attained a height of 0.78 m at the time of wheat sowing, which increased to 1.05 m at the time of wheat harvest, showing a height increment of 0.27 m (34.6%). The basal diameter also increased from 2.15 cm to 3.07 cm, indicating normal vegetative growth during the cropping season. Under agri-hortisystem (Guava + Wheat), guava plants exhibited slightly higher growth compared to the agri-silvi-horti system. The tree height increased from 0.79 m to 1.10 m, while the basal diameter increased from 2.16 cm to 3.10 cm during the same period. The slightly greater growth of guava under the guava + wheat system may be attributed to reduced interspecific competition for light, moisture and nutrients, as eucalypts trees were absent in this system. In contrast, in the agri-silvi-horti system, eucalypts trees might have exerted mild competitive effects due to their rapid growth and extensive root system, which could influence the availability of soil moisture and nutrients. These results suggest that young eucalypts plantations exert limited competition on horticultural species, particularly during the early years when canopy development and root expansion are still moderate. Similar findings were reported in agroforestry studies where tree-crop interactions during early plantation stages had minimal influence on the growth of associated crops or horticultural plants (Sharma *et al.*, 2022).

Soil properties

Soil properties of the experimental field are presented in Table 2. The soil is non saline, low in

TABLE 1
Growth performances of eucalypts and Guava in different agroforestry systems at sowing and harvest of wheat crop

| Tree species/ Agroforestry system | Height (m) | | Basal diameter (cm) | | DBH (cm) | |
|---------------------------------------|----------------|-------------|---------------------|-------------|----------------|-------------|
| | November, 2019 | April, 2020 | November, 2019 | April, 2020 | November, 2019 | April, 2020 |
| Eucalypts (Eucalypts + Guava + Wheat) | 4.99 | 7.43 | 7.25 | 11.34 | 6.81 | 10.96 |
| Guava (Eucalypts + Guava + Wheat) | 0.78 | 1.05 | 2.15 | 3.07 | - | - |
| Guava (Guava+ Wheat) | 0.79 | 1.10 | 2.16 | 3.10 | - | - |

organic carbon and available N, medium in available P and K. The soil chemical properties of the experimental field (0-15 cm depth) indicated that the soil was slightly alkaline in reaction (pH 8.0) and non-saline (EC 0.92 dS m⁻¹). The organic carbon content (0.38%) and available nitrogen (131.4 kg ha⁻¹) were found to be low, while available phosphorus (11.6 kg ha⁻¹) and potassium (280.2 kg ha⁻¹) were in the medium range. The results suggest that the soil possessed moderate fertility status but was deficient in organic matter and nitrogen, which may influence crop productivity in the system. Integration of tree species such as eucalypts and guava in agroforestry systems can gradually improve soil fertility through litter fall, root biomass turnover and nutrient recycling. Tree litter decomposition contributes organic matter to the soil, which enhances soil organic carbon and improves nutrient availability over time. Similar findings with low organic carbon and nitrogen but medium phosphorus and potassium in semi-arid agroforestry soils has been reported by Rajan *et al.* (2024) and Kumar (2024). Likewise, Amorim *et al.* (2022) reported that soils under agroforestry initially exhibit moderate fertility but gradually improve due to litter fall and nutrient recycling by tree components. A global analysis by Zhang *et al.* (2025) also showed that agroforestry systems significantly enhance soil organic carbon and nutrient cycling compared with conventional cropping systems. These findings are supported by the observations of Sirohi and Bangrwa (2017), who reported higher availability of soil nutrients under poplar-based cropping systems. Similarly, Sirohi

et al. (2022b) observed significantly greater availability of nitrogen (N), phosphorus (P), and potassium (K) under poplar windbreak agroforestry systems compared with sole cropping systems.

Crop growth studies of wheat

Plant height of wheat at different growth stages

The plant height of wheat at different growth stages under various agroforestry systems is presented in Table 3. The results revealed that plant height of wheat increased progressively with crop growth from 30 DAS to harvest in all the systems. At 30 DAS, plant height ranged from 30.42 to 31.52 cm, and the differences among treatments were non-significant, indicating that tree components had negligible influence on early crop growth. However, significant differences were observed at later stages of crop growth. At 60 DAS, the highest plant height was recorded under sole wheat (62.22 cm) followed by guava + wheat (59.38 cm) and eucalypts + guava + wheat (56.68 cm). Similarly, at 90 DAS, the maximum plant height was recorded in sole wheat (84.51 cm) followed by agri-horti system (81.93 cm) and agri-silvi-horti system (78.91 cm). At 120 DAS, plant height ranged from 85.91 to 90.07 cm. At harvest, the highest plant height (91.38 cm) was recorded under sole wheat, which was significantly higher than both agroforestry systems. Among the agroforestry systems, the guava-based agri-horti system recorded higher plant height (89.07 cm) compared with eucalypts-based agri-silvi-horti system (87.16 cm). The comparatively higher

TABLE 2
Soil chemical properties of the experimental field

| Depth (cm) | pH | EC _{1,2} (dS/m) | OC (%) | Available nutrients(kg/ha) | | |
|------------|-----|--------------------------|--------|----------------------------|------|-------|
| | | | | N | P | K |
| 0-15 | 8.0 | 0.92 | 0.38 | 131.4 | 11.6 | 280.2 |

TABLE 3
Plant height of wheat crop at different stages of crop growth in different agroforestry systems

| System | Plant height (cm) | | | | |
|---------------------------------------|-------------------|--------|--------|---------|------------|
| | 30 DAS | 60 DAS | 90 DAS | 120 DAS | At harvest |
| Eucalypts (Eucalypts + Guava + Wheat) | 31.52 | 56.68 | 78.91 | 85.91 | 87.16 |
| Guava (Guava+ Wheat) | 31.06 | 59.38 | 81.93 | 87.39 | 89.07 |
| Control | 30.42 | 62.22 | 84.51 | 90.07 | 91.38 |
| Mean | 31.00 | 59.43 | 81.79 | 87.79 | 89.20 |
| CD at 5% | NS | 3.93 | 4.29 | 2.88 | 2.52 |

plant height observed in the guava based agri-horti system compared with the eucalypts based agri-silvi-horti system may be attributed to the less dense canopy structure and relatively lower root competition of fruit trees. Eucalypts trees are known to produce dense canopy and have extensive root systems, which may limit the availability of growth resources for intercrops. Consequently, the reduction in plant height under tree based systems becomes more pronounced at later stages of crop growth when crop demand for resources increases. Similar findings have been reported by Sirohi *et al.* (2022b) who observed that wheat grown under poplar based agroforestry systems recorded significantly lower plant height compared with sole wheat due to reduced light availability and competition for soil moisture and nutrients. The results are also in agreement with the findings of Chavan *et al.* (2024) who reported that crop growth parameters including plant height of wheat were significantly reduced under tree based agroforestry systems compared to sole cropping, mainly due to shading effects and competition for growth resources. However, despite slight reductions in crop growth parameters, agroforestry systems provide several long-term ecological benefits such as improved soil fertility, enhanced carbon sequestration and better nutrient cycling. Integration of trees with crops improves soil organic matter through litter deposition and root biomass turnover, which ultimately contributes to sustainable land use systems. These findings are also supported by Sirohi *et al.* (2022a) who emphasized that tree based agroforestry systems significantly improve soil health and long-term productivity of agricultural lands in north-western India.

Yield and yield attributing parameters of wheat

The yield and yield attributing parameters of wheat were significantly influenced by different

agroforestry systems (Table 4). The number of effective tillers m^{-2} at harvest varied significantly among treatments. The highest number of effective tillers was recorded in the control (318.00 m^{-2}), which was significantly superior to the eucalypts + guava + wheat system (304.11 m^{-2}). The reduction in the number of effective tillers under agri-silvi-horti system may be attributed to competition between trees and crops for light, nutrients and soil moisture, particularly under eucalyptus which has a dense canopy and extensive root system. Days taken to maturity of wheat were also significantly affected by different agroforestry systems. Wheat under eucalypts based system took the maximum number of days to maturity (169.22 days) which was significantly higher than the control (161.44 days). The delay in crop maturity under tree based systems may be due to partial shading and modified microclimatic conditions beneath tree canopies. Similar results were observed for other yield attributing parameters such as spike length, grains per spike and test weight. The maximum spike length (12.09 cm) was recorded in sole wheat, which was significantly higher than that recorded under the eucalypts based system (10.89 cm). Likewise, the number of grains per spike was significantly higher in the control (41.66 grains spike⁻¹) compared to 37.86 grains spike⁻¹ under agri-silvi-horti system. Test weight also followed a similar trend where the highest value (42.12 g) was observed in sole wheat and was significantly superior to the eucalypts based system (37.89 g).

Grain yield, biological yield and harvest index also differed significantly among the treatments. The highest grain yield (5.05 t ha⁻¹) was recorded in the control (sole wheat), which was significantly higher than the eucalypts based agri-silvi-horti system (4.49 t ha⁻¹). Among agroforestry systems, guava based agri-horti system recorded significantly higher grain yield (4.81 t ha⁻¹) compared to the eucalypts based system,

TABLE 4
Yield and yield attributing parameters of wheat crop in different agroforestry systems

| System | No. of effective tillers/ m^2 at harvest | Days taken to maturity (No.) | Spike length (cm) | Grains/spike (No.) | Test weight (g) | Grain yield (t/ha) | Biological yield (t/ha) | Harvest index (%) |
|-------------------------------------|--|------------------------------|-------------------|--------------------|-----------------|--------------------|-------------------------|-------------------|
| Eucalypts (Eucalypts+ Guava+ Wheat) | 304.11 | 169.22 | 10.89 | 37.86 | 37.89 | 4.49 | 10.44 | 43.02 |
| Guava (Guava+ Wheat) | 312.22 | 162.89 | 11.63 | 39.01 | 40.36 | 4.81 | 11.06 | 43.57 |
| Control | 318.00 | 161.44 | 12.09 | 41.66 | 42.12 | 5.05 | 11.52 | 43.89 |
| Mean | 311.44 | 164.52 | 11.54 | 39.51 | 40.12 | 4.79 | 11.01 | 43.49 |
| CD at 5% | 9.53 | 2.96 | 0.82 | 3.00 | 3.13 | 0.39 | 0.83 | 0.45 |

indicating relatively lower competition between guava trees and wheat crop. A similar trend was observed for biological yield where the highest value (11.52 t ha⁻¹) was recorded in the control, followed by guava based system (11.06 t ha⁻¹) and eucalypts based system (10.44 t ha⁻¹). Harvest index also showed significant differences, with the highest value recorded in the control (43.89%), followed by guava based system (43.57%) and eucalypts based system (43.02%).

The reduction in yield and yield attributes of wheat under agroforestry systems may be attributed to tree-crop competition for light, water and nutrients, as well as shading effects under tree canopies. Fast growing species like eucalypts can create stronger competition due to deeper and wider root systems and higher transpiration demand. In contrast, fruit trees such as guava generally exert relatively lower competitive effects, which explains the comparatively higher wheat yield observed in the agri-horti system.

Comparable results were also reported by Chavan *et al.* (2023) who found that yield attributes of wheat including number of effective tillers, spike length and grains per spike were significantly reduced under tree based agroforestry systems compared with sole cropping due to reduced solar radiation and altered microclimatic conditions beneath tree canopies.

Likewise, Dhyani *et al.* (2017) reported that crop productivity in agroforestry systems may decline slightly in comparison with sole cropping because of resource sharing between trees and crops, but the overall system productivity and sustainability are significantly enhanced. The present findings are in agreement with Sirohi *et al.* (2025) who observed that wheat grain yield was reduced under eucalypts based agroforestry systems but remained economically viable due to additional income from tree components. Similar findings were reported by Singh *et al.* (2020) in a *Leucaena leucocephala*-wheat alley cropping system, where above- and below-ground competition significantly reduced wheat productivity compared to sole crop conditions

Furthermore, Jose (2009) emphasized that although intercrop yield may be reduced under tree based systems due to competition, agroforestry systems improve long-term soil fertility, nutrient cycling, carbon sequestration and ecosystem stability, thereby contributing to sustainable agricultural production. These findings clearly indicate that while sole wheat recorded the highest yield in the present study, the guava based agri-horti system proved to be more compatible with wheat compared to the

eucalyptus based agri-silvi-horti system, suggesting that careful selection of tree species is essential for improving crop productivity under agroforestry systems.

CONCLUSION

Among the agroforestry systems evaluated, the guava-based agri-horti system exhibited superior wheat growth and yield attributes compared to the eucalypts-based agri-silvi-horti system. The highest grain yield was recorded under the agri-horti system, indicating comparatively lower competitive effects of guava than eucalyptus. Overall, the results suggest that wheat can be effectively cultivated under tree-based land-use systems with only moderate yield reductions, while providing additional long-term economic and ecological benefits such as timber and fruit production and enhanced system sustainability. Therefore, the guava-based agri-horti system may be considered a more compatible and productive option for integrating wheat in semi-arid agroforestry systems.

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