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Growth, yield and economic analysis of wheat-eucalypts based agroforestry system in semi-arid region of India

Stanley Kombra, K Singh, Chhavi Sirohi, Sneh Yadav, Karishma Nanda, Kajal and Pooja

Abstract
The goal of the current study was to assess the impact of a 7 × 3 m, roughly 3-year-old eucalyptus plantation on the growth and yield characteristics of wheat, and vice versa. The largest growth gain in plant height (14.1 m) and DBH (10.3 cm) of eucalypts was recorded with wheat intercropping rather than solitary eucalypts (without crop). At harvest, wheat intercrop with eucalypts had the highest number of plants (65) per meter row length, plant height (97.5 cm), dry matter accumulation (1635.2 g/m^2), tillers/m^2 (319.5), grain yield (4.56 t/ha), straw yield (5.72 t/ha), biological yield (10.03 t/ha), harvest index (45.56%), and attraction index (96.33%). However, under eucalypts plantations, the maximum number of days required for spike appearance (50%) and days to maturity of wheat were noted. Under the eucalyptus plantation, there was an average drop of 10.86% in effective tillers/m^2, 18.42 in spike length, and 8.60 in number of grains per spike in wheat when compared to the control. In comparison to the control, the cropping system of wheat and eucalyptus showed the highest net return (Rs. 99265.6/ha). In comparison to the control (1.36), the total B: C ratio was calculated to be greater in the eucalyptus-based agroforestry system (1.66).

Keywords: Eucalypts, wheat, food security, sustainability, agroforestry

Introduction

Agroforestry is gaining a higher position and becoming a specialized science with integration of both crops and trees. Agroforestry has the enormous potential to achieve the social, economic, and ecological objectives of a large population while simultaneously enhancing the soil fertility (Dollinger and Jose, 2018) [11], enhancing ecosystem services (Kuyah *et al.*, 2016) [19], and reducing the effects of climate change (Ospina, 2017) [23]. Agroforestry directly or indirectly contributes significantly to some of the most difficult goals, including eradicating poverty, preventing hunger, achieving food security, improving nutrition, promoting sustainable agriculture, promoting healthy lives and well-being, reducing the effects of climate change, sustainable forestry, and preserving biodiversity (Waldron *et al.* 2017, Montagnini and Metzel, 2017) [31, 21].

Wheat (*Triticum aestivum*) is an economically important stable crop. wheat produced globally has tripled since the end of the Green Revolution. but, in recent times, the yields have reached a plateau. In order to meet the food needs of a 9.6 billion-person world population by 2050, the World Bank estimates that worldwide wheat output would need to rise by 60%, which is difficult because of depleting land and water supplies and shifting climatic conditions. In South Asia's Indo-Gangetic Plains (IGP), which span almost 14 million hectares, the rice-wheat cropping system (RWCS) is the main agricultural production system (Alam *et al.*, 2016) [1]. Although RWCS is vital for ensuring future food security and livelihood of millions of people in South Asia, the path to success has been affected by declining soil health, groundwater resources (Bhatt *et al.*, 2016) [2], mono-cropping of cereal-cereal system, increasing climate variabilities, and changing socio-economic dynamics (Dubey *et al.*, 2020, Mishra *et al.*, 2021) [12, 20].

In the northern area of our country, Eucalypts (*Eucalyptus tereticornis*), Shisham (*Dalbergia sissoo*), Poplar (*Populus deltoides*), and Jandi (*Prosopis cineraria*) are highly significant tree species for agroforestry and are widely distributed. Due to their quick rate of growth, high timber value, and capacity for coppicing, eucalypts are a significant species in agroforestry systems in India.

Additionally, it can survive in a wide range of settings, including humid woodland regions and dry tropical regions. Around 700 species of the Myrtaceae family's genus Eucalyptus have been used historically to cure wounds, lesions, and other illnesses. Despite the fact that growing *Eucalyptus tereticornis* was originally done to generate pulpwood, the wood is now also used to make packing cases, poles, crates, furniture, and low-cost houses in rural areas. It is known that eucalypts species create a variety of volatile compounds in significant amounts, particularly isoprenoids, which are stored in glands that are widely dispersed throughout the leaf parenchyma and bark. Functional groups of chemicals found in most plant products, such as alcohols, phenols, terpenes, and ketones, are recognized to have antimicrobial characteristics. According to species, clones, and soil conditions, eucalypts exhibit a wide range of production responses (Onyekwelu *et al.* 2014) [22]. The purpose of the current study is to evaluate the economics of a eucalyptus-based wheat-based agroforestry system as well as the impact of eucalyptus, one of the fastest growing industrial trees, on the growth and yield of wheat.

Materials and Methods

The current study was conducted in the Department of Forestry's Research Farm, which is 215.2 meters above mean sea level and located at 29° 09' N latitude, 75° 43' E longitude in the semi-arid region of north-western India. The climate is subtropical-monsoonal, with an annual rainfall of 350-400 mm, 70% of which occurs between July and September. The soil at the test site has a saline pH of 7.9, an EC of 0.78 dS/m, low levels of available nitrogen (140 kg/ha) and organic carbon (0.42%), medium levels of available P (12 kg/ha), and high levels of available K (284 kg/ha).

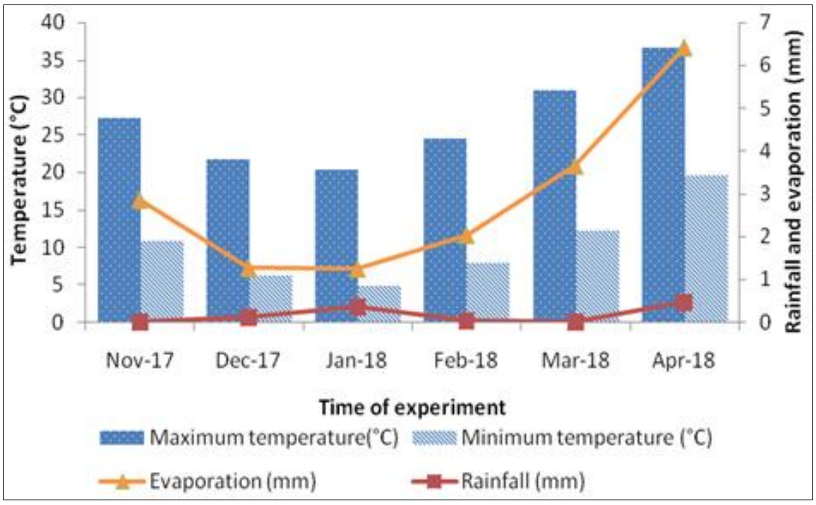

Fig 1: Monthly weather data of experimental site from November to April

The present study was conducted in 2.8 years old plantation of Eucalyptus teriticornis planted at a spacing of 7 × 3 m. In the first week of November, wheat (Triticum aestivum) cv. HD-2967 was seeded during the winter (Rabi) season with a row-to-row spacing of 22.5 cm and a seed rate of 100 kg/ha in both the eucalyptus plantation and the control (without tree). In accordance with university guidelines and practices, the suggested fertilizer dosage of 150 kg N, 60 kg P_2O_5, and 60 kg K_2O ha^{-1} was used in this experiment.

The growth of wheat under eucalyptus trees and the control crop (sole wheat) were observed. Twenty days after sowing (DAS), the number of plants inside a row measuring one running meter in length were counted four times. Wheat plants' height (in centimeters), fresh and dry matter accumulation (in grams), and the number of tillers per meter of row length were measured at intervals of 30 days and at harvest. In the case of dry matter, the samples were first sun-dried before being dried in an oven at 70 °C until a constant weight was reached and the samples were weighed on a digital balance. The time it took for a 50% spike to emerge, the length of maturity, the number of effective tillers, the length of the spike, and the number of grains/spike were all noted, along with control. Sun dried bundles from each plot were weighed before threshing to record biological yield, and the clean grains collected were weighed to record grain yield. Straw yield was calculated by removing grain weight from biological yield and converting to t/ha using the appropriate conversion factor. A composite sample of grains was taken from the final product, and 1000 grains were counted and weighed to determine the test weight in grams (g). The following formula was used to calculate the harvest index (%) and attraction index (%): Harvest Index (%) = [Grain yield/Biological yield] × 100

Attraction index (%) = (Grain yield/Straw yield) × 100

The height (m), diameter at breast height (cm), and crown spread (m) of 10 randomly selected eucalypts under study were measured before and after wheat harvesting. The B: C ratio of both systems (eucalyptus-wheat agroforestry system and sole wheat) was computed. The investigation's data were statistically examined utilizing the Paired t-test and Statistical Analysis Software.

Results and Discussion

Growth performance of eucalypts

The overall growth of the eucalypts under investigation increased with age (Table 1). The maximum plant height (14.1 m) and DBH (10.3 cm) of eucalypts were higher with wheat intercrop than with solitary eucalypts (without crops). However, no difference in eucalypt crown spread was detected with or without crops. The increased growth of eucalypts with intercropping may be due to timely and adequate fertilizer, irrigation, and other cultural operations.

Additionally, our current findings are very similar to those of Pinto *et al.* (2005) [24] in Eucalyptus grandis.

Table 1: Growth performance of eucalypts with and without wheat crop

Time	Height (m)		DBH (cm)		Crown Spread (m)	
	With Wheat	Without Wheat	With Wheat	Without Wheat	With Wheat	Without Wheat
October, 2017	12.2	12.4	9.2	9.4	2.7	2.8
April, 2018	14.1	13.9	10.3	10.1	3.1	3.1

Number of plants (per meter row length) and plant height (cm): In comparison to the eucalyptus-based cropping system, the control (single crop) had the maximum number of wheat plants (65), while the eucalyptus-based cropping system had the lowest number of plants (56), a drop of 13.85% (Table 2). Sarvade *et al.* (2014) [28] also found data that were consistent. According to their findings, under eucalyptus plantations, allelochemicals had an inhibitory effect that reduced the number of plants per meter of wheat row length.

Table 2: Number of plants per meter row length in wheat at 20 DAS under eucalypts plantation and control

Treatment	Number of plants per meter row length
With eucalypts#	56
Control (Devoid of tree)	65
t-value	5.27*
P value	0.0133

* Significant at 0.05 percent level of P, # eucalypts planted at a spacing of 7×3 m

The significantly lesser plant height of wheat was recorded under eucalypts than control (without tree) from 30 DAS to harvest (Fig. 2) and differed significantly at different time intervals (60 DAS upto harvest) in both the systems. The maximum plant height (97.5 cm) was found at harvest in control however, it was statistically at par at 120 DAS (95.2cm). Under eucalypts plantation the percent reduction in plant height of wheat was 6.33, 9.34, 10.31, 13.34 and 14.05 at 30, 60, 90, 120 DAS and at harvest, respectively over control. The present findings are in agreement with the results of Kaur *et al.* (2010) [15] in poplar based intercropping of wheat over control and revealed that low interception of radiation under poplar based agroforestry system reduced the photosynthetic efficiency of wheat which resulted in poor growth performance. A similar pattern of plant height in wheat under various agroforestry systems have also been reported by several research workers (Rani *et al.* 2011) [27].

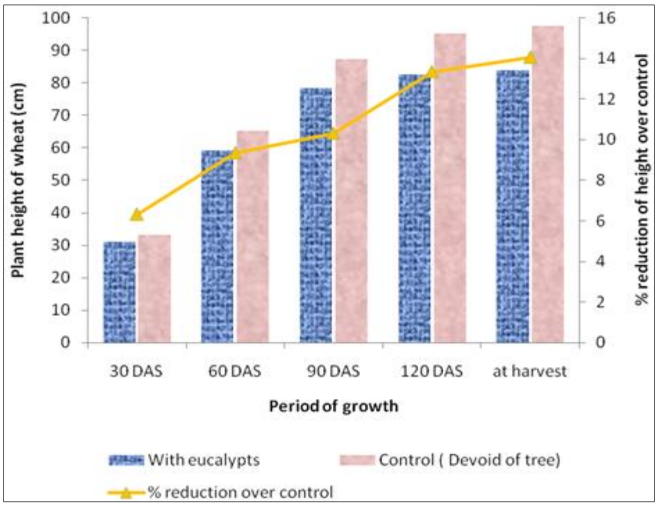

Fig 2: Plant height (cm) at different time intervals in wheat under eucalypts plantation and control

Fresh and dry matter accumulation (g/m^2)
The fresh and dry matter accumulation in wheat at different stages of growth was significantly lower under eucalypts than control (Figure 3). A reduction of 16.24, 15.08, 21.13, 21.82, 21.56 percent in fresh weight and 14.85, 15.12, 20.17, 20.44 and 18.95 percent in dry weight (Figure 4) of wheat at 30, 60, 90, 120 DAS and at harvest respectively was recorded under eucalypts over control (devoid of tree). The lower fresh and dry matter accumulation of wheat under eucalypts based agroforestry system may be due to the lower availability of sunlight and more competition between tree and crop for moisture and nutrients than in control (devoid of tree). Similar findings earlier were reported Chesney *et al.* 2010 [8], Prasad *et al.* 2010 [25] in different agroforestry systems.

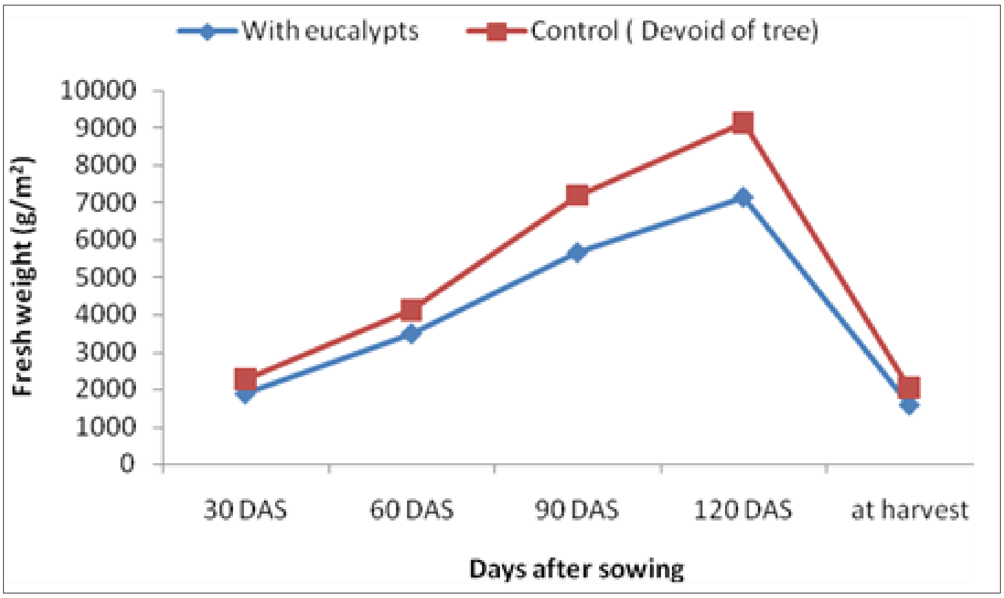

Fig 3: Fresh matter accumulation (g/m^2) at 30 days interval in wheat under eucalypts plantation and control

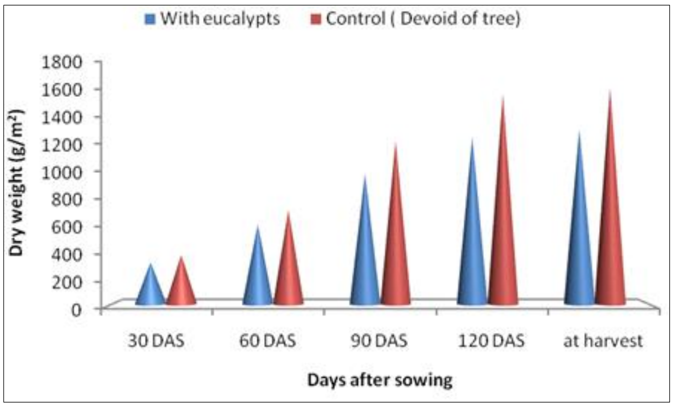

Fig 4: Dry matter accumulation (g/m^2) at 30 days interval in wheat under eucalypts plantation and control

Number of tillers (m^2)

The greatest number of wheat tillers was seen at 120 DAS (Figure 5), and the average growth in tillers was seen from 60 to 90 DAS greater than from 90 to 120 DAS under eucalyptus trees and in open (sole wheat). These findings are broadly consistent with the findings of Sirohi *et al.* (2016) [30] in wheat under poplar planted at 5x4 m spacing.

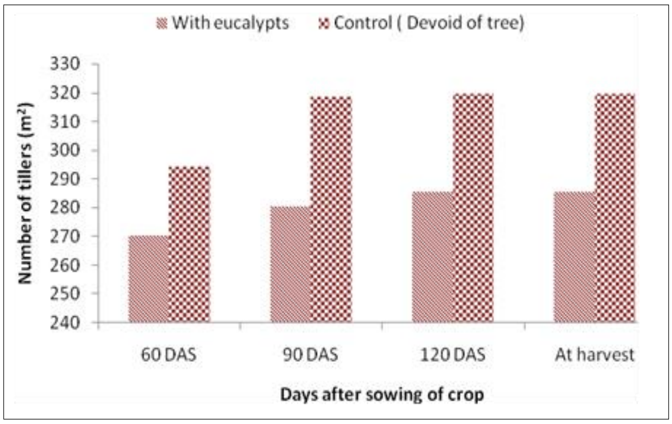

Fig 5: Number of tillers (m^2) in wheat at 60, 90, 120 days after sowing and at harvest under eucalypts plantation and control

Phenological characters

In compared to the control (no trees), the eucalyptus planting required 50% additional days for spike appearance and maturity. When compared to the control (single crop), the eucalypts-based cropping system delayed wheat spike emergence and maturity by around 10 days. The crop's lower ability to photosynthesize was much more likely to explain the maximum number of days required for spike emergence (50%) and the late maturity of wheat beneath eucalypts. Singh *et al.* (2005) [29] observed similar findings in various wheat cultivars grown with eucalyptus.

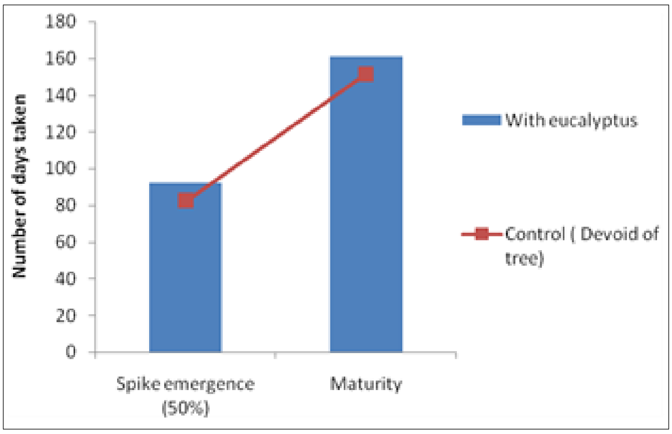

Fig 6: Phenology of wheat under eucalypts plantation and control

Effective tillers/m^2, length of spike (cm), number of grains per spike and test weight (g)

Effective tillers per m2 in wheat were reduced by 10.86% under eucalypts compared to the control (open). Wheat spike length fell by 18.42% on average under eucalypts as compared to the control (Table 3). Furthermore, Chauhan *et al.* (2011) [27] discovered a 33.6% drop in wheat spike length under a 6-year-old poplar plantation compared to the control, affecting grain yield. The study found that the control cropping system generated more wheat grains and spikes than the eucalyptus-based cropping system (Table 3). When compared to the control (a single wheat crop), 8.60% fewer grains were produced per spike. Clemente *et al.* (2015) [9] previously reported similar findings in an agroforestry system based on *Eucalyptus teriticornis*. The test weight of wheat crop grown under eucalyptus plantation was 5.29% lower than that of the control (Table 3). The current study found that wheat production and yield attributing characteristics were considerably affected by eucalyptus plantation due to its evergreen nature and greater shade effect. Previously, Kumar *et al.* (2013) [18] observed a decrease in test weight of annual crops in eucalypts-based agroforestry systems compared to solitary cropping systems.

Table 3: Yield attributes of wheat under eucalypts plantation and control

Treatment	Effective tillers (m^{-2})	Length of spike (cm)	Number of grains/spike	Test weight (1000 grain) (g)
With eucalypts#	275.1	9.3	42.5	43.0
Control (Devoid of tree)	308.6	11.4	46.5	45.4
t-value	20.18*	7.65*	1.92	1.94
P value	0.0003	0.0046	0.1499	0.1483

* Significant at 0.01 percent level of P, # eucalypts planted at a spacing of 7×3 m

Grain, straw and biological yield (t/ha)

Wheat grain yield was highest (4.56 t/ha) in the control (single crop). Under eucalyptus plantations, wheat grain yield decreased by 18.64% compared to the control. Previous research (Kumar *et al.* 2013 and Chauhan *et al.* 2015) [18, 7] suggests that the decreased grain yield of wheat beneath eucalyptus plantations may be due to a lack of light and increased competition for moisture and nutrients. When compared to the control, wheat straw yield fell by 16.96% beneath eucalyptus trees (Figure 7). Wheat straw yield declined at a slower rate when compared to grain yield when eucalyptus was planted. The current findings are also consistent with those of Kohli and Saini (2003) [17] and Kidanu *et al.* (2005) [16]. The maximum biological yield (10.03 t/ha) was observed in control than eucalypts based cropping system (Figure 7). The decrease in the biological yield under eucalypts was more may be due to the poor growth and yield attributing parameters (plant height, spike length, number of grains per spikes and test weight), which may have been affected by the micro-environmental changes under tree canopy (Gill *et al.* 2009) [13]. Corroborative findings also been reported by Bisht *et al.* (2017) [4].

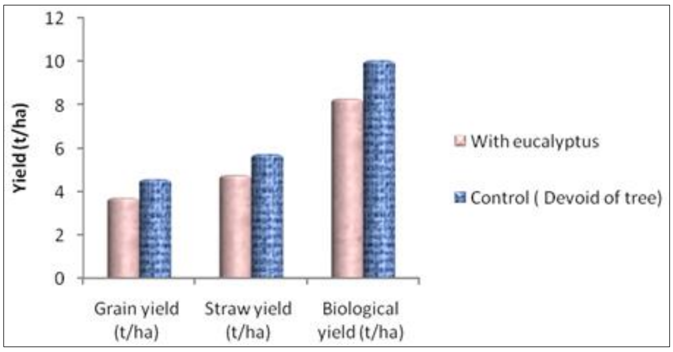

Fig 7: Yield of wheat under eucalypts plantation and control

Harvest and attraction index (%)

Under eucalyptus plantation, the harvest index of the wheat crop was negatively impacted (Figure 8). In the current study, during the experimentation period, the control plantation had a higher harvest index (45.56%) than the eucalyptus plantation. In comparison to eucalyptus plantation, wheat crop recorded a much higher attraction index (Figure 8). Eucalyptus trees reduced the attractiveness index of wheat by 18.65 percentage points compared to the control. This variance in biomass output under the eucalypts plantation may be the cause of the deviation in harvest and attractiveness index. Sirohi *et al.* (2016) [30] in several wheat types under poplar and Bisht *et al.* (2018) [3] in eucalypt plantations observed similar outcomes.

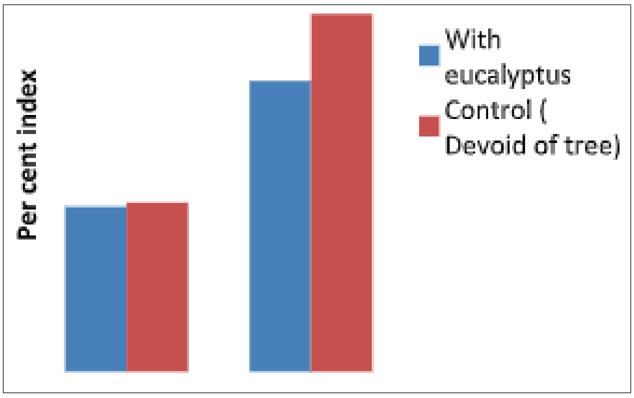

Fig 8: Harvest and attraction index (%) of wheat under eucalypts plantation and control

Economic analysis of the eucalypts based agroforestry system

The highest cultivation cost (Rs.149040.4/ha) and gross returns (Rs. 248306.0/ha) were found to be greater in wheat under a eucalyptus-based cropping system, while solitary cropping had the lowest. However, the eucalypts + wheat system had a greater net return (Rs. 99265.6/ha) and benefit-to-cost ratio (B:C ratio), which was 1.66. The findings are consistent with the findings of Dhillon *et al.* (2018) [10], who showed a higher gross return in a eucalypts-barley agroforestry system vs mono farming of barley.

Table 4: Economics of eucalypts + wheat based agroforestry system and control (sole crop)

	Agroforestry	Sole crop
Cost of cultivation (Rs./ha)	149040.4	68863.6
Gross return (Rs. /ha)	248306.0	93672.2
Net return(Rs./ha)	99265.6	24808.6
Cost/benefitratio	1.66	1.36

Conclusion

In the current study of a Eucalypts-wheat based cropping system in a semi-arid ecosystem, grain yield of wheat was maximum (4.56 t/ha) in the control (single wheat), and grain yield reduction in wheat under eucalypts plantation (7x3 m) was 18.64% above the control. However, eucalypts reduced wheat straw output by 16.96% compared to the control. The results showed that the eucalypts + wheat based agroforestry system produced the highest gross returns (Rs. 248306.0/ha) and the highest net returns (Rs. 99265.6/ha) when compared to solitary cropping (control). Similarly, the maximum B:C ratio (1.66) was assessed under the eucalypts + wheat system, indicating that the eucalypts-based agroforestry system will be more profitable to farmers than solitary cropping (1.35).

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