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OPTIMIZING WHEAT PRODUCTIVITY UNDER EUCALYPTUS INFLUENCE: A STRATEGIC CULTIVAR SELECTION APPROACH FOR NORTHERN INDIA

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ABSTRACT
Agroforestry systems offer a sustainable alternative to monocropping, particularly in arid and semi-arid regions, due to their ecological and socio-economic benefits. Eucalyptus-based agroforestry systems have gained popularity among farmers in the Indo-Gangetic region of India, primarily due to the high industrial demand for Eucalyptus products such as pulpwood, paperwood, and polewood. The present study investigates the impact of Eucalyptus tereticornis windbreaks on wheat yield and soil nutrient status under an agroforestry setup. Five wheat varieties, WH-1105, WH-542, HD-2967, HD-943, and DPW-621-50, were evaluated over two consecutive years with Eucalyptus tree lines oriented in East–West and North–South directions. Results indicated that yield reduction in wheat was most pronounced near the tree line (T1 and T2 treatments) due to resource competition, while wheat yield improved with increasing distance from the trees. Among the varieties tested, HD-2967 consistently outperformed others in terms of grain yield. Furthermore, soil nutrient analysis revealed significantly higher levels of available nitrogen (278.3 kg/ha), phosphorus (14.2 kg/ha), and potassium (335.3 kg/ha) at 2 meters from the tree line post-harvest. The study concludes that strategic spatial arrangement and varietal selection are critical for optimizing wheat productivity in Eucalyptus-based agroforestry systems.

KEYWORDS: Boundary plantation, *Eucalyptus tereticornis*, shade-tolerant, wheat varieties, orientation, and agroforestry system

INTRODUCTION
Food insecurity in developing countries is increasingly aggravated by rising population pressure, rapid urbanization, industrial expansion, climate change, and progressive land degradation. These multifaceted challenges necessitate innovative and sustainable land-use strategies that not only ensure food production but also restore ecological balance. Among the available approaches, agroforestry systems (AFS), which integrate trees with crops and livestock, are widely recognized for their potential to enhance productivity and ecosystem resilience (Mukhlis *et al.*, 2022).

In the Indian context, AFS primarily encompasses two strategies: cultivation of food crops within forested areas and establishment of tree–crop combinations in agricultural landscapes. Such integrated practices are instrumental in reducing deforestation and mitigating land degradation while simultaneously improving farm productivity through positive tree–soil–crop–livestock interactions. Agroforestry is increasingly viewed as an ecologically sound practice capable of producing agricultural outputs without environmental degradation while enhancing climate resilience (Wilson & Lovell, 2016). As a sustainable land management system, agroforestry combines perennial tree species with food crops to improve soil health, reduce erosion, and promote long-term sustainability (Dobhal *et al.*, 2024; Gitari *et al.*, 2024).

Compared with sole cropping, agroforestry systems offer multiple benefits, including enhanced carbon sequestration, amelioration of microclimatic extremes, and reduced soil erosion, making them a preferred strategy for sustainable intensification of agriculture (Chavan *et al.*, 2020). Recent studies emphasize the scope for diversifying Indian farming systems with suitable agroforestry models that match regional ecological and socio-economic conditions (Handa *et al.*, 2020a; Handa *et al.*, 2020b; Bisht *et al.*, 2021). For instance, windbreak agroforestry systems are particularly effective in semi-arid regions, where they enhance ecosystem services by reducing wind velocity, controlling soil erosion, and conserving soil moisture (Zhang *et al.*, 2013; Akanwa *et al.*, 2020). Furthermore, leaf litter decomposition in these systems contributes to soil organic matter buildup, thereby improving physico-chemical properties and overall fertility (Bisht *et al.*, 2020).

The incorporation of short-rotation, fast-growing tree species into agroforestry systems has been advocated as a viable option for meeting both food and industrial raw material demand (Sarvade *et al.*, 2014). Such species not only provide economic returns to farmers through timber and pulpwood markets but also supply essential nutrients to associated crops (Yang *et al.*, 2016). Among these, Eucalyptus occupies a prominent position due to

its rapid growth, high adaptability to salt-affected soils, and suitability for boundary plantations on bunds and marginal lands (Jinger *et al.*, 2023). Its non-palatable foliage makes it advantageous for boundary planting, while its self-pruning nature minimizes competition for light with understory crops.

In northern India, particularly in Haryana and Punjab, farmers have widely adopted eucalyptus and poplar plantations in association with wheat (*Triticum aestivum* L.) and mustard. The popularity of eucalyptus is attributed to its high productivity (10–30 m^3 ha^{-1} yr^{-1}), strong market demand, and capacity to generate significant supplementary income. The success of these plantations has been further supported by initiatives such as the Planting Stock Improvement Programme (PSIP), which has substantially improved productivity and profitability (Jones & Lal, 1989; Berry *et al.*, 2024).

Wheat, the most important rabi season crop of the Indo-Gangetic plains, accounts for 88.31 million tonnes of production under the existing AFS. Boundary plantations of eucalyptus have been shown to enhance net returns, as the dual income from timber and wheat outweighs that from wheat monoculture. Nevertheless, optimizing planting geometry, selecting stress- and shade-tolerant wheat varieties, and refining management practices remain essential for reducing competition and maximizing system productivity. Against this backdrop, the present study was designed to evaluate the performance of different wheat varieties under Eucalyptus tereticornis bund plantations in northern India. The investigation focused on tree–crop interactions, including the influence of planting geometry, tree density, and shading on wheat morphology (leaf area, internode length), reproductive traits (flower initiation, fruit set), and grain yield at varying distances from tree rows. The outcomes are expected to provide insights into refining agroforestry practices, thereby enhancing system sustainability and economic viability in the region. The need for site-specific crop management strategies to ensure agricultural productivity and enhance the resilience of major crops is further emphasized by climate variability and environmental stress (Bhattacharjee et al., 2024). In addition, data-driven agricultural approaches offer opportunities to integrate crop performance, soil properties, and climatic information into site-specific management decisions. Machine-learning-based analytical frameworks may support future prediction of wheat yield under varying tree–crop competition conditions, although their application requires suitable field datasets and independent model validation (Taqvi, 2025).

MATERIAL AND METHODS

Site Description

The present investigation was conducted at the Main Experimental Area of the Department of Forestry, CCS Haryana Agricultural University, Hisar, India (29°10′N, 75°43′E; 215 m asl), situated in the semi-arid region of northwestern India. The site experiences a subtropical monsoonal climate with 350–400 mm means annual rainfall, of which nearly 70–80% is received during July–September. Summers are extremely hot (40–45 °C in May–June), while winters are cold, with minimum temperatures occasionally reaching 0°C in January.

The experiment was laid out in a factorial randomized block design (RBD) with three replications. A mature Eucalyptus tereticornis plantation, established in 2006 on previously monocropped wheat land, served as the tree component. East–west and north–south bund plantations were used to evaluate the interaction of wheat varieties at varying distances from the eucalyptus tree line. Six treatments were imposed: T1 (2 m), T2 (4 m), T3 (6 m), T4 (8 m), T5 (10 m), and T6 (sole crop control). Five high-yielding wheat varieties, WH-1105, HD-2967, WH-542, DPW-621-50, and HD-943, were sown in the first week of November during both years of study, maintaining a row spacing of 22.5 cm and a seed rate of 100 kg ha^{-1}. Identical sowing practices were followed in the control plots without trees. Fertilizer application was carried out as per recommended doses (150 kg N, 60 kg P_2O_5, 60 kg K_2O ha^{-1}). At sowing, half of the nitrogen and the entire dose of phosphorus and potassium were applied, with the remaining nitrogen top-dressed at the Crown Root Initiation (CRI) stage using urea. The same experimental procedure was repeated in the second year to ensure consistency of results. This design enabled a systematic evaluation of tree–crop interactions, particularly the influence of eucalyptus proximity on wheat growth, yield, and varietal performance under semi-arid agroforestry conditions.

Soil Sampling for analysis of soil nutrient status

To assess the impact of eucalyptus windbreaks on soil fertility, four soil samples were systematically collected along transects laid in both east–west and north–south directions of the eucalyptus plantation. Sampling was carried out at 2 m intervals, beginning at 2 m and extending up to 10 m from the tree line, along with samples from an adjacent control site without trees. Each soil sample was taken from the 0–15 cm depth in three replications, providing representative data on surface soil fertility.

Soil sampling was conducted twice during each study year, once before wheat sowing in October (pre-crop season) and again after wheat harvest in April (post-crop season). This seasonal approach enabled the evaluation of temporal changes in soil nutrient dynamics under the tree–crop interface. Following collection, all soil samples were air-dried, gently crushed, and sieved through a 2 mm mesh before storage and subsequent laboratory analysis. Standard protocols were employed for soil fertility assessment: available nitrogen (N) was estimated by the alkaline permanganate method (Subbiah and Asija, 1956), organic carbon (%) was determined by the Walkley and Black partial oxidation method (Walkley and Black, 1934), available phosphorus (P) was analyzed using the sodium bicarbonate extraction method (Olsen et al., 1954), and available potassium (K) was quantified by the neutral normal ammonium acetate method (Jackson, 1973). This methodological framework allowed for a comprehensive assessment of how eucalyptus windbreak plantations influenced soil organic matter and macronutrient availability across spatial (distance from tree line) and temporal (seasonal) scales.

Wheat crop yield

The grain yield of wheat was assessed using the quadrate method at harvest. Sampling was carried out at progressive distances of 2, 4, 6, 8, and 10 m from the base of the eucalyptus tree line to capture the gradient of tree–crop interaction. For each treatment, crop samples were collected from a 1 m² quadrate, ensuring uniformity and representative yield estimation. Following the recording of all growth and yield attributes, the harvested samples were sun-dried, after which the produce from the net plot was hand-threshed. The cleaned grain was subsequently weighed, and the grain yield per plot was calculated. This procedure provided an accurate assessment of the influence of eucalyptus proximity on the productivity of different wheat varieties.

Tree Growth

Tree growth attributes were systematically recorded to assess the performance of Eucalyptus tereticornis under agroforestry conditions. Observations on tree height, diameter at breast height (DBH), and canopy spread were taken for 15 randomly selected trees during both seasons (April and November) of the initial and final experimental years. Tree height (m) was measured from the base to the terminal shoot using a Ravi's Multimeter, while DBH (cm) was recorded at 1.37 m above ground level with a measuring tape. The canopy width was determined by measuring crown spread in the north–south and east–west directions for each tree, and the average values were expressed in meters. From these parameters, the current annual increment (CAI) was calculated to quantify growth performance. Measurements were recorded separately for trees planted in east–west and north–south windbreak orientations.

To evaluate the shade effect of eucalyptus on the wheat crop, light intensity at the crop canopy level was monitored using a lux meter. Readings were taken monthly at six time points during the day: 7:00 a.m., 9:00 a.m., 11:00 a.m., 1:00 p.m., 3:00 p.m., and 5:00 p.m., both under the agroforestry system and in adjacent open-field control plots. These measurements provided insights into the diurnal and seasonal variation in light availability and its potential influence on crop growth beneath the tree canopy. The experimental data were subjected to analysis of variance (ANOVA) using SPSS statistical software (version 20.0). Before analysis, the data were tested for normality and homogeneity of variances, confirming their suitability for parametric statistical procedures. Following validation, ANOVA was performed to assess the significance of treatment effects. Wherever significant differences were detected, mean separation was carried out using Duncan's Multiple Range Test (DMRT) at the 5% probability level ($p < 0.05$) to ensure robust comparison among treatments.

RESULTS AND DISCUSSION

Soil organic carbon and available N, P, & K

During both years of the experiment, soil organic carbon (SOC), available nitrogen, phosphorus, and potassium increased near the eucalyptus tree line (Figures 2 to 5). However, the sole cropping (control) had lower nutrient concentrations than the eucalyptus windbreak agroforestry system. The status of soil organic carbon (SOC) and available nutrients was significantly affected by the East-West orientation of the eucalyptus windbreak, and it decreased as the distance from the eucalyptus tree line increased (Figure 2). In both aspects of East-West direction, the eucalyptus windbreak had higher soil organic carbon (0.70 and 0.68%), and it was significantly higher recorded in the southern aspect compared to the northern aspect (0.66 and 0.66%), up to 4 m distance from the eucalyptus tree line after wheat crop harvesting during the final year. Whereas, the lesser soil organic carbon has been observed at a 10 m distance from the eucalyptus tree line compared to other distance treatments. Sole cropping (control) exhibited significantly lower organic carbon (0.36%) before sowing of the wheat crop. In general, the soil organic carbon (SOC) content after wheat crop harvest was moderately higher than before sowing of the wheat crop during both years of experimentation, as well as in both row directions. In this result, it was also observed that the available soil N was higher at different distances in the eucalyptus windbreak agroforestry system compared to the sole crop (control) during both consecutive years (Figure 3). The available soil N (304.2, 296.5, and 291.6 kg ha-1) was significantly higher under the eucalyptus windbreak agroforestry system in the southern aspect up to a distance of 6 m from the tree line, followed by the western, eastern, and northern aspects after harvesting of the wheat crop (Figure 3). Meanwhile, available N was lower in both cases at a distance of 8 to 10 m from the eucalyptus windbreak agroforestry system's tree line in both years, but significantly higher than in the sole crop (control). A similar trend has been followed in available P and K at both aspects of East-West row directions of eucalyptus windbreak (Figures 4 and 5). The availability of soil P and K content was significantly higher under row directions of eucalyptus windbreak AFS as compared to the sole crop (control). In general, the amount of organic carbon content after wheat crop harvest was slightly higher than before sowing of the wheat crop during both years of the experiment in the eucalyptus windbreak AFS.

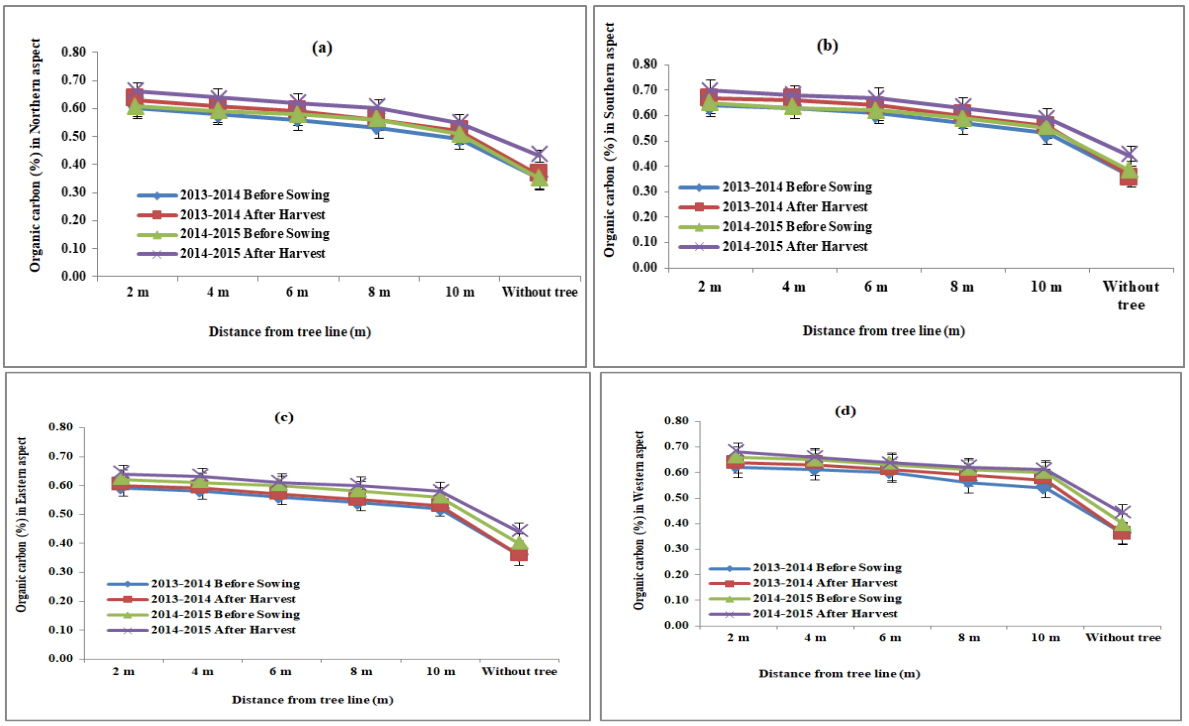


Fig 3: a-d Available N (kg ha^{-1}) Before sowing and after harvesting of winter wheat varieties during initial to final year comprising delimited by a row of eucalyptus trees (6 and 7 year old) in East -West and North -South directions (E -W tree line divide farmlands into two aspects i.e. Northern and Southern and N -S tree line divide into Eastern and western aspect), error bars are ± standard error (SE)

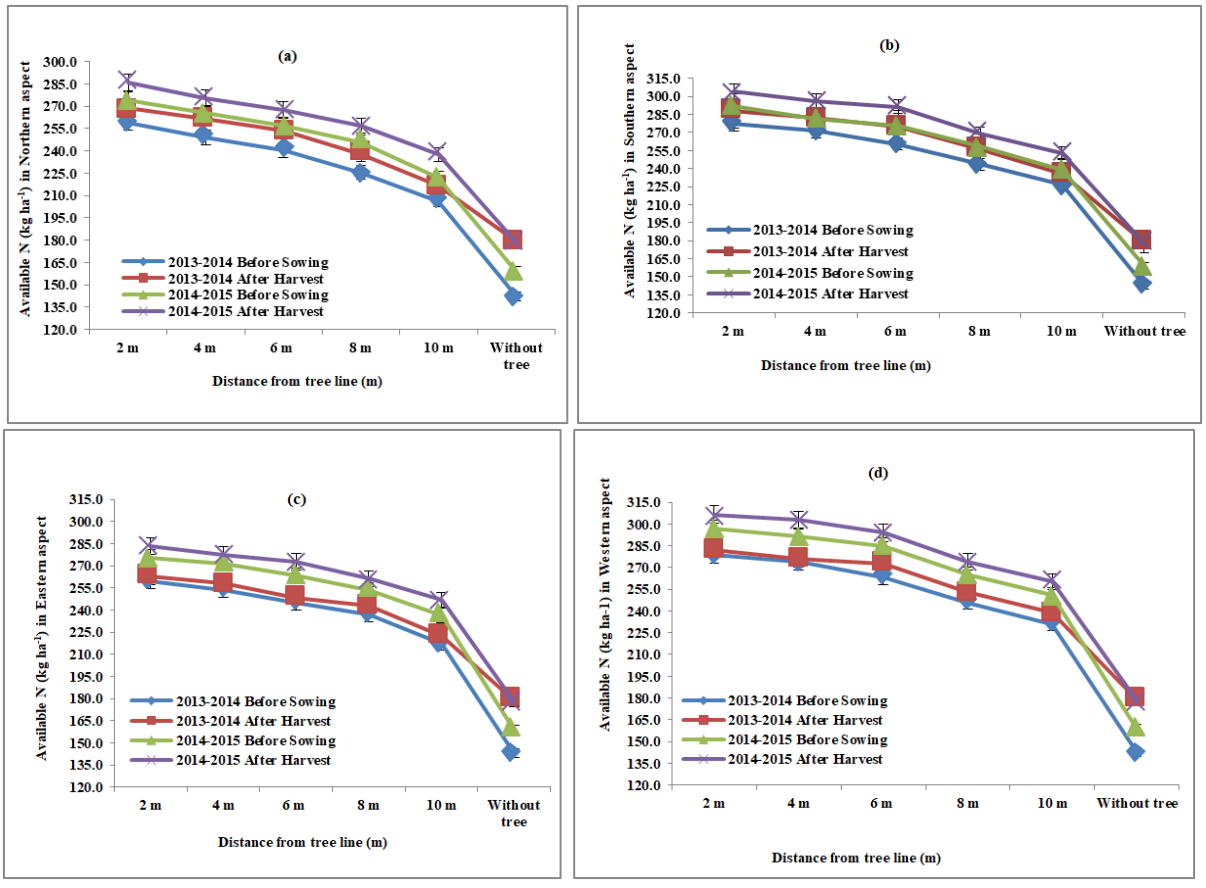


Fig 4: a-d Available P (kg ha^{-1}) Before sowing and after harvesting of winter wheat varieties during initial to final year comprising delimited by a row of eucalyptus trees (6 and 7 year old) in East -West and North -South directions (E -W tree line divide farmlands into two aspects i.e. Northern and Southern and N -S tree line divide into Eastern and western aspect), error bars are ± standard error (SE)

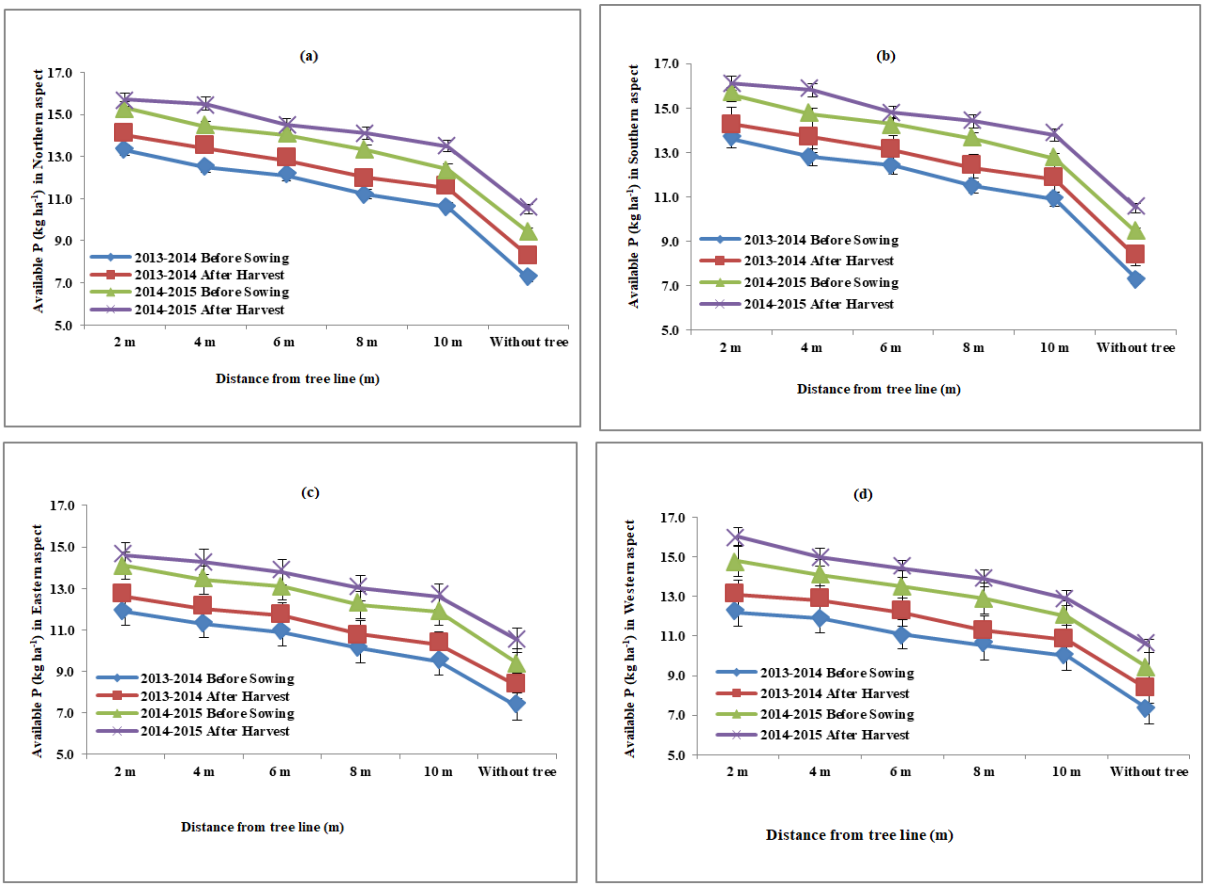


Fig 5: a-d Available K (kg ha^{-1}) Before sowing and after harvesting of winter wheat varieties during initial to final year comprising delimited by a row of eucalyptus trees (6 and 7 year old) in East -West and North -South directions (E -W tree line divide farmlands into two aspects i.e. Northern and Southern and N -S tree line divide into Eastern and western aspect), error bars are ± standard error (SE

Soil fertility status increases with the available nutrients in soil organic matter and sequestered organic carbon, thereby enhancing soil microorganisms' metabolic activities (Borjesson *et al.,* 2016). Soil organic carbon is higher near the tree line, which might be due to the high levels of organic carbon and the addition of large quantities of leaf litter and other plant parts (Peichl *et al.,* 2006). Near the tree line (2m to 6 m distance), the availability of soil N, P, and K was significantly higher in the planting of eucalyptus trees in a row from east to west on the farm boundary. This similar trend has also been followed in *Acacia nilotica-based* AFS windbreak (Bargalli *et al.,* 2009; Eddy, W.C., and Yang, W.H. 2022). In the upper layer of soil, the maximum amount of nutrients (N, P, K) is available, but soil nutrient status decreases with increasing soil depth, and available nutrients were higher in an agroforestry system than in the control (Chauhan *et al.,* 2012). Tree-based agroforestry systems in soil organic carbon found higher amounts may be due to the addition of leaf litter, which enhances the decomposition of organic matter, helps to increase the nutrients in soil, and provides nutrients to plants through soil, as well as helps to improve the fertility status of soil (Bisht *et al.,* 2020; Meena *et al.*, 2020). The richest amount of organic matter in the intercropping system could be ascribed to the fact that leaf fall, annual fine roots biomass recycled and exudation of roots, which reduces the oxidation of organic matter under tree shades and increases the cycling of soil nutrients, which could be important for both tree species and associated crops (Cardon *et al.,* 2013; Panwar, P *et al.*, 2018). Tree-based agroforestry systems in soil water contents vary at various distances from the plant and different soil depths, and it was found to be maximum in agroforestry systems compared to control (Bayala and Wallace 2015; Ong *et al.* 2014). The beneficial effects of tree-based agroforestry systems, on a sustainable basis, help improve soil physico-chemical conditions, increase organic matter, and build soil fertility. (Bargali *et al.,* 2009; Chavan, *et al.*, 2022; Singh *et al.*,2022). In addition, plant growth-promoting microorganisms like nitrogen-fixing bacteria like Azotobacter can also help in nutrient availability and crop growth, but microbial activity was not measured in the present study and should be explored in future research (Ghatage et al., 2024).

Growth of Eucalyptus

Tree growth was significantly affected by different row directions of eucalyptus windbreak agroforestry systems. However, tree height was significantly higher in the North-South direction than in the East-West direction of the eucalyptus windbreak. The eucalyptus planted in the North-South direction had attained greater height and DBH (22.5 m and 29.9 cm, respectively) as compared to the East-West direction of eucalyptus (Table 1). In the East-West and North-South directions of the eucalyptus boundary plantation, the average tree DBH ranged between 28.1 cm and 28.7 cm, and 29.2 cm and 29.9 cm, respectively. When averaged across years, an increment of

about half a meter was observed in TH during the initial year compared with the final year in the eucalyptus windbreak agroforestry system. This investigation confirmed that trees had a significant effect on available light intensity in both years of the experiment. The tree DBH has no significant effect on plantation direction, whereas tree height varies significantly across directions (Chauhan *et al.,* 2012; Faria *et al.,* 2015; Tonini *et al.,* 2021; Singh *et al.*, 2023). The results confirmed that higher light intensities (1036.4 and 1028.3 Lux) were recorded on the southern aspect than on the western aspect (874.3 and 857.6 Lux) at 1.00 pm, at a distance of 10 m, compared with near distances from the tree line in March. The tree growth and volume yield parameters have been observed to be better on the southern aspect of the agroforestry system (Johar *et al.*, 2017).

Table 1: Mean effects of years for tree height (TH; m) and Diameter at breast height (DBH; cm) of eucalyptus trees evaluated in both directions (East-West and North-South) during the initial year and final year

Different directions	INITIAL YEAR			FINAL YEAR		
	Height (m)	DBH (cm)	Canopy width (m)	Height (m)	DBH (cm)	Canopy width (m)
North-South	21.4±1.05	28.7±1.27	6.3±1.01	22.5±1.08	29.9±1.47	6.9±1.03
East-West	20.5±1.08	28.1±1.21	6.1±1.04	21.9±1.02	29.2±1.51	6.5±1.05

Grain yield (t/ha)

All-inclusive treatments and years had inconsistent effects on grain yield across all wheat varieties in both directions of the eucalyptus windbreak agroforestry system (AFS). The grain yield of all wheat varieties exhibited significant differences across all aspects in the eucalyptus windbreak. However, wheat variety HD-2967 had the maximum grain yield (3.4 t/ha) in the southern aspect as compared to the northern aspect in the east-west direction of the eucalyptus windbreak. Among all five wheat varieties, grain yield declined significantly up to a distance of 4 m from the tree line (Treatments T1 & T2) in both directions during both years of the study. Grain yield of wheat varieties (HD-2967, HD-943, DPW-621-50, WH -542, WH-1105) were significantly affected with treatments T_1& T_6: sole crop (figure 6 and 7). The yield reduction percentage was found to be higher in the northern aspect near the tree line (0-2 m), and it followed the order: HD-943(88.8%) > WH-542 (74.3%) > DPW-621-50(72.0%)> HD-2967(60.0%) under eucalyptus windbreak AFS. Whereas, treatment T_6 (control) had the highest grain yield (5.40 and 4.90 t/ha) in the wheat variety WH-1105, followed by WH-542 (3.90 and 3.50 t/ha) from the initial to the final year. The perusal of the data showed inconsistent effects of eucalyptus tree line direction on wheat grain yield across different aspects, which can be attributed to microsite amelioration from a favorable environment created by shade and leaf litter addition. A substantial increase in grain yield of wheat varieties was observed in treatment T_2 beyond treatment T_5 in the southern aspect of the east-west direction of the eucalyptus windbreak (Figure 6, b). Whereas, in the north-south direction of the eucalyptus, treatment T1 significantly (p<0.05) affected the grain yield of all wheat varieties, HD-2967, WH-542, DPW-621-50, HD-943, and WH-1105 (Figure 6, c-d). A similar pattern was also observed in the next successive growing season of the wheat crop in all aspects of the eucalyptus windbreak (Figure 7, a-d). In this study, the results indicated that each tree row direction and the distance from the tree line (treatments T_1, T_2, T_3, T_4, and T_5) are the major factors determining the effect of the tree canopy on wheat yield intercropped with the tree windbreak. The least negative effects of the presence of eucalyptus boundary plantation on crop yield have been found for diverse kinds of wheat varieties at various distances from the tree line. According to initial observations, wheat crop cultivation has been a successful approach at greater distances from the eucalyptus tree line, and adverse effects on crop yield were also less until the rotation age of the eucalyptus windbreak AFS. The southern aspect had higher grain yield than other aspects because of the maximum availability of solar radiation, which supports better photosynthetic activity and faster plant metabolic growth, resulting in higher yield and productivity. Before sowing, leaf fall is incorporated into the soil, but after sowing, it impedes the emergence and/or growth of the wheat crop. The incorporation of leaf fall is inversely related to wheat crop yield. In the southern aspect, enhanced yield may be due to the addition of leaf litter through leaf fall, which improves soil fertility and provides nutrients to plants through the soil. Significantly, Light, moisture, and nutrient uptake are the most important factors that support vegetative growth and higher yields in agroforestry systems (Prasad *et al.,* 2010; Uniyal and Chhetri, 2010). Furthermore, researchers observed that crop yield increased with greater distance from the tree line, as the southern aspect allows light to fall on the field throughout the day compared to other aspects (Chauhan *et al.,* 2012). Crop yield reduction is lower in field plots with wider canopy spacing than in agroforestry systems with closer canopy spacing (Johar *et al.*, 2017; Bisht *et al.,* 2022). The grain yield of all wheat varieties was found to be maximum at a distance of 4 m from the tree line, which increased considerably (Nadagouda *et al.,* 1997). In a poplar windbreak, AFS in wheat yield decreases at a distance near the tree base and increases in the number of grains per m2 at a distance of 8m to 10 m from the tree base as compared to near the tree base (Pardon *et al.,* 2018). Among different wheat varieties, HD-2967 was found to be a stress-tolerant variety compared to others, and it performed better in shade conditions under a eucalyptus-based agroforestry system (Bisht *et al.,* 2021). Other scientists have also revealed that the shading effect of the hybrid walnut during high temperatures reduces the desiccant effect of wind velocity and thereby increases the yield of winter crops (Arenas-Corraliza *et al.,* 2018; Mantino *et al.,* 2023). In the present study, the yield reduction rate was lower in the southern aspect of the east-west row direction as compared to other directions of the eucalyptus windbreak

AFS. However, among all the wheat varieties, it represents better performance in the away tree line as compared to near the tree line (distance 2-8 m) eucalyptus windbreak AFS. The reason for the lower yield of the wheat crop in the eucalyptus windbreak AFS up to an extent of 8m from the tree line, but far distance from the tree line had maximum yield, might be due to the lesser competition effect for different resources, *i.e.* solar radiation, moisture and soil nutrients, between trees and crop (Mead *et al.,* 2010; Nabati and Farnia 2021; Sirohi *et al.* 2022).

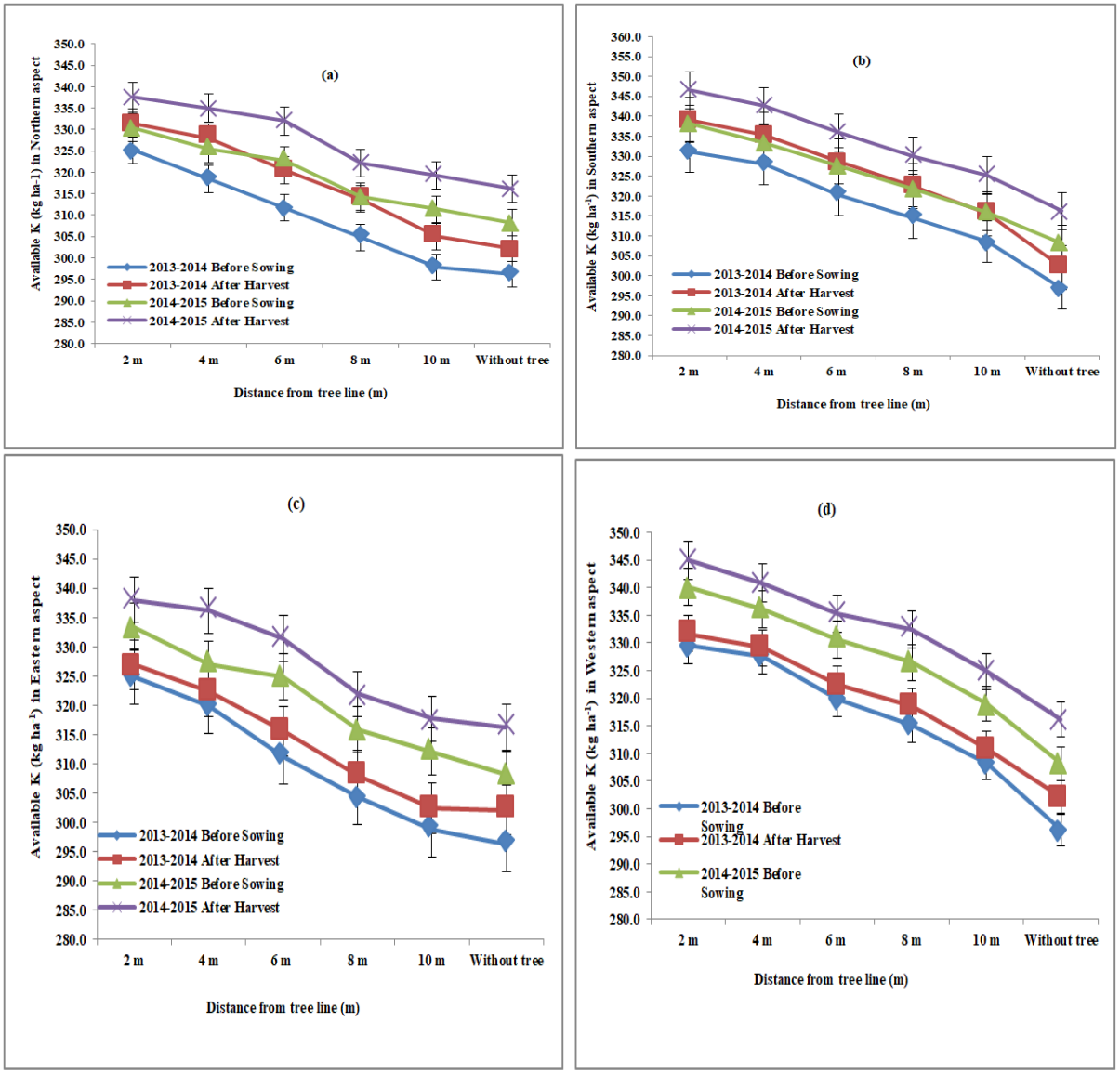
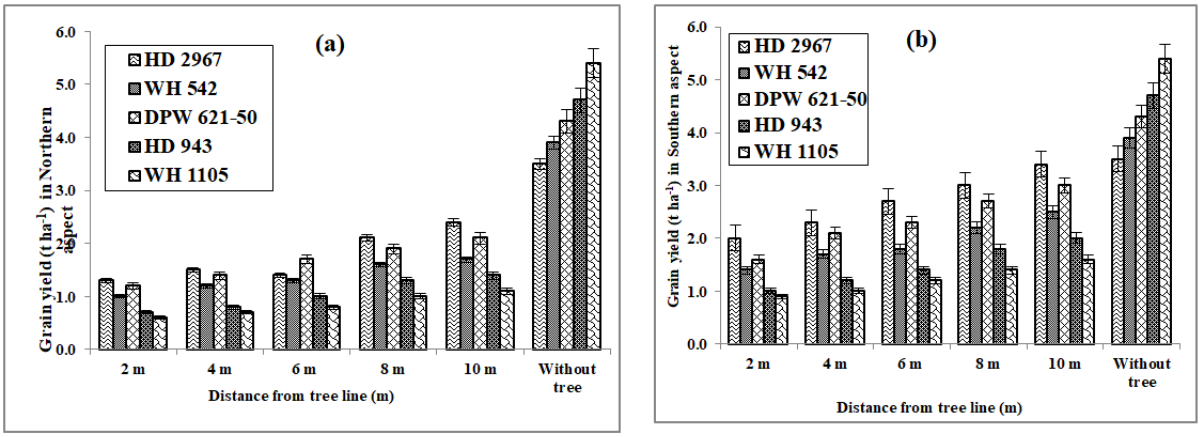


Fig 6: a-d Grain yield (t ha^{-1}) of wheat varieties during initial year comprising delimited by a row of eucalyptus trees in Northern and Southern and Eastern and western aspect), error bars are ± standard error (SE), values with the same letter are not significantly different from one another at significance level $p<0.05$



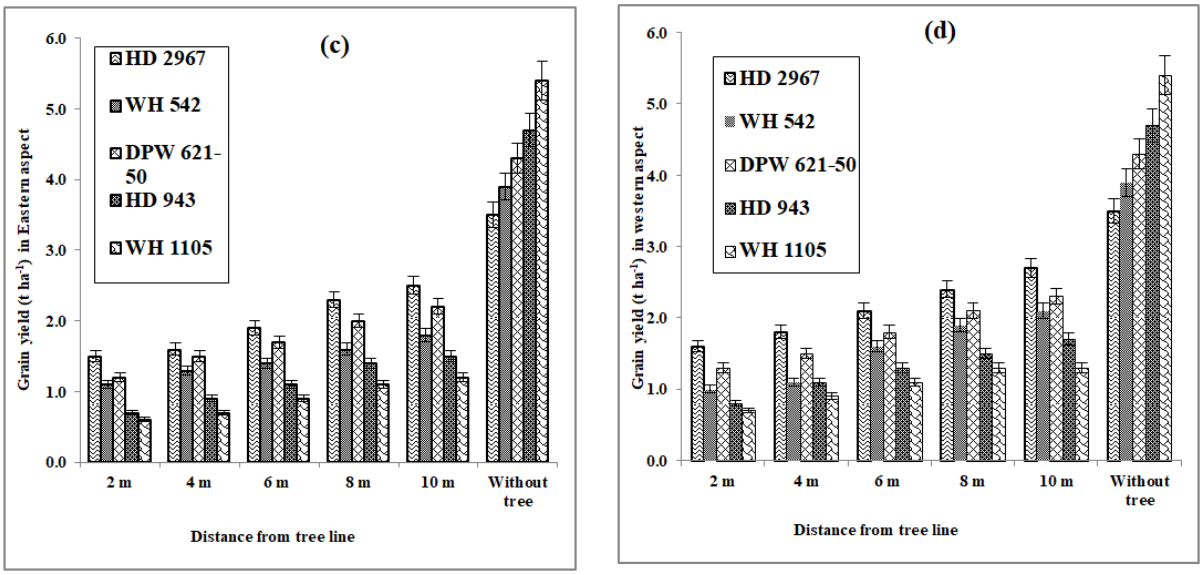


Fig 7: a-d Grain yield (t ha^{-1}) of wheat varieties during the final comprising delimited by a row of eucalyptus trees in Northern and Southern and Eastern and Western aspects), error bars are ± standard error (SE), values with the same letter are not significantly different from one another at significance level $p<0.05$

CONCLUSION

Eucalyptus windbreak AFS in the growth and yield of wheat varieties was observed varied spatially (both in direction and distances). In general, among all different wheat varieties, there was reduced grain yield and maximum reduction in production in the northern aspect whereas, minimum yield reduction in the southern aspect in AFS. However, wheat cultivar HD- 2967 performed better in shade conditions and also produced the more yield when intercropped along with eucalyptus trees row in East to West and North to South directions. Eucalyptus + Wheat is ideal model for semi-arid region farmers. Wheat crop yield in regard to the varietal performance within the eucalyptus-wheat AF system in the semi-arid region of Haryana, India notably positive relation distance from the tree line (10 m, treatments T_5). In a semi-arid region Eucalyptus windbreak AFS is best option for improving productivity and sustainability. It is quite evident from the results that under shade conditions, wheat grain yield was considerably more affected near the tree line (treatments T_1 and T_2) by the presence of short rotation eucalyptus windbreak AFS than increasing distances from tree line and the control plot (without trees) too. At the same time the result has shown that eucalyptus windbreak AFS had favorable effect on microclimatic conditions from near the tree line of 1m to 6m distance (T_1 to T_3). Eucalyptus agroforestry system has to be established with appropriate silviculture treatments and choose right site of plantation *i.e.* particular location and tendency to optimize properly for its positive values and to reduce the negative effects between trees and crops, and this scientific management not only construct the income generation for improving of socio-economic value but also is concerned with the ecosystem sustainability. Furthermore, in changing of climates, windbreaks can play a significant role in adaptation strategies as agricultural producers and small-scale farmers too. This study concludes for optimizing the production potential of eucalyptus windbreak AFS, properly, windbreak orientation and provided tree spacing can also enhance microclimate, sustainability and ecosystem services of the system and eventually accomplish higher growth, productivity and economic returns.

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