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EDITED BY
Tibebu Kassawmar,
Addis Ababa University, Ethiopia

REVIEWED BY
Adornis Dakarai Nciizah,
Agricultural Research Council of South Africa (ARC-SA), South Africa
Rajesh Kaushal,
Indian Institute of Soil and Water Conservation (ICAR), India
Ramesh Thakur,
Michigan Technological University, United States

*CORRESPONDENCE
Akshay Kumar
✉ abakshaybhardwaj90@gmail.com;
✉ bhardwaj2k18@gmail.com

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Evaluation of growth, yield attributes, and yield of wheat varieties under *Terminalia chebula* trees

Akshay Kumar*, Meenakshi Gupta, L. M. Gupta, Sarabdeep Kour and Punit Choudhary

Division of Silviculture and Agroforestry, Sher-E-Kashmir University of Agricultural Sciences and Technology, Jammu, India

Agroforestry plays a key role in the Indian economy in terms of tangible and intangible benefits. Agroforestry can simultaneously satisfy three important objectives, namely, protecting the ecosystems, producing a high-level output of economic goods, and increasing income and basic needs of the rural population, in addition to maintaining the resource base. In the Jammu subtropics, many fruit trees are grown with grasses or as the sole crop. There is not much awareness among farmers about the benefits of agroforestry. To overcome this, we conducted a field trial at the experimental farm of the Division of Agroforestry, Chatha, with the aim of exploring the possibility of growing different wheat varieties as an intercrop under the canopy of harad (*Terminalia chebula* Retz.) trees planted at a spacing of 5 × 4 m^2. Three wheat varieties, namely, JAUW-598, WH-1080, and RSP-561, were grown under the *Terminalia chebula* trees, and growth and yield parameters were recorded at two distances from the base of the tree (0–1 m and 1–2 m). This study investigates the impact of distance from *Terminalia chebula* (harad) trees on the growth and yield of different wheat varieties in the agroclimatic conditions of Jammu and Kashmir. The primary objective was to determine the optimal spacing that minimizes competition for resources between the trees and crops, thereby enhancing wheat productivity. By evaluating key growth parameters and yield at varying distances from the tree base, this research aims to provide actionable insights for optimizing intercropping systems in the region. The growth and yield of varieties were significantly reduced under shade as compared to sole cropping. Maximum spike length (13.91 cm), tillers/plant (7.36), grains/spike (33.62), and grain yield (42.46 qha^{-1}) were recorded in the variety RSP-561 grown in the open conditions. Overall, RSP-561 performed better among all the other varieties with a yield reduction of 47.83 and 12.15% at a distance of 0–1 m and 1–2 m, respectively, under shade as compared to the open conditions. All wheat varieties performed better at a distance of 1–2 m away from the tree base as the amount of shade/competition is less compared to a distance of 0–1 m from the tree base. The study concluded that wheat can be successfully grown at a distance of 1–2 m from the tree base to attain an additional income from the *Terminalia chebula* orchard.

KEYWORDS

competition, growth, intercrop, *Terminalia chebula*, yield attributes

Introduction

Agroforestry has been commonly practiced for many centuries all over the world as a way to increase agricultural sustainability and slow down the negative effects of agriculture, e.g., soil erosion. There are numerous agroforestry systems in use all over the world. Agroforestry aims at combining woody perennials with agricultural crops in such a way that positive ecological and economic interactions between the components could take place. This combination of woody perennials with agricultural crops can be made possible via a spatial arrangement, a rotation of components, or both. Agroforestry provides assets and income from wood energy, diversified crop rotations, improved soil fertility, enhanced local climatic conditions, and ecosystem services and reduces human impacts on natural forests (Chavan and Dhillon, 2019).

Agroforestry creates a micro-climate beneath the crops, which can enhance the productivity and yield of these crops. Productivity in agri–silvi system is comparatively higher than the productivity of sole agriculture (Dhyani et al., 2013). Soil quality and its production capacity can be restored and improved by adopting an agroforestry system such as agri–silvi system, which provides a way to sustain agricultural production (Bijalwan et al., 2020) Integrating trees (forest and fruit) enhances overall productivities and incomes by ameliorating harsh environment of the area (Kumar and Bijalwan, 2021).

Harad or Haritaki botanically known as *Terminalia chebula* Retz. is a medium-to-large deciduous tree. It is one of the multipurpose and medicinal agroforestry tree species, which is found in many states. In Jammu and Kashmir, it was found in sub-tropical forests ranging from 300 m to 1,630 m amsl (Sharma and Thakur, 2015). The dried fruit is also used in Ayurveda as a purported antitussive, cardiotonic, homeostatic, diuretic, and laxative (Priya et al., 2024). In India, production of *T. chebula* fruit is estimated to be 1,00,000 tons of which 20% is exported to countries such as Europe and the United States (World Agroforestry Centre, 2017). In Jammu and Kashmir State, the annual production of harad fruit is approximately 500 tons (as per conversation with a local trader of Jammu).

Triticum aestivum, commonly known as wheat, is the most important and staple food crop. It is the most widely grown cereal crop during the *Rabi* season (November–April), which is intercropped with a number of tree species. In Jammu and Kashmir, wheat is grown in an area of 281.87 thousand hectares (Anonymous, 2017). In Jammu, wheat is generally grown as a monocrop and an intercrop in orchards in some places.

Given the potential for competition between trees and crop plants, it is important to maximize complementary interactions and minimize any competitive interactions. In addition to the selection of suitable tree species and crops, another important way to achieve maximization is by understanding parameters such as the minimal distance required between intercropped tree rows and crop plants to avoid significant competition for light and nutrients. Hence, the experiment was aimed to ascertain the influence of distance from the base of the tree (*Terminalia chebula*) on the growth and yield of different wheat varieties.

Materials and methods

This experiment was carried out at an experimental field of the Division of Agroforestry, SKUAST Jammu, to study the growth, yield attributes, and yield under the open and *Terminalia chebula*-based agroforestry system. The experimental site falls under the subtropical zone of the Jammu division of Jammu and Kashmir union territory, India, with a mean annual rainfall of approximately 1,100 mm. The maximum temperature rises up to 45°C during June, and the minimum temperature falls to 1°C during January. The agri-silviculture system is comprised of *Terminalia chebula* trees planted at a spacing of 5 m x 4 m. The plantation was 7 years old, and three wheat (*Triticum aestivum* L.) varieties, *viz.*, WH-1080, JAUW-598, and RSP-561, were sown on 19 November 2018 in between the tree rows and in the open (without trees) to serve as control. The experiment was laid down in a randomized block design with seven treatments and three replications. Two distances from the base of the tree were taken, i.e., D_1—up to 1 m and D_2—from 1 to 2 m. Nine plots of size 10×4 m^2 were prepared under *Terminalia chebula* trees and nine in open. Treatment combinations were allotted to the plots randomly under the canopy and open conditions. Proper fertilization is a critical factor in producing optimum and profitable wheat yields. As per the soil test value, a mixture of 120 kg of nitrogen, 80 kg of phosphorus, and 40 kg of potassium per hectare was applied through urea, DAP, and muriate of potash. While sowing the half dose of nitrogen (N), a full dose of phosphorus (P) and potassium (K) was given as a basal dose while rest of the nitrogen was applied as top dressing at 30–35 days.

Plant population/m^2

The plant population was counted by using a quadrat of 1m^2 from the base of the tree at both distances.

Plant height (cm)

The height of plants was measured from ground level to the tip of the plant with the help of a measuring scale. The plant height was recorded in centimeters.

Number of tillers/plant

Tillers were counted by using the 1m^2 quadrant at a distance of 0–1 and 1–2 m from the sample plot. Tillers were counted at maturity and expressed as tillers per plant.

Spike length (cm)

Length from the neck node to the apex of the spike was measured in centimeters.

Number of grains/spike

From the selected plants, the number of grains was counted and represented as number of grains/spike.

Thousand-grain weight (g)

A total of 1,000 grains were collected from each sample plot, and their weight was measured using electronic balance and expressed in grams.

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Grain yield (q/ha)

Harvested crop produced from the selected sample plot was thrashed with a thresher. The grain yield was recorded in kg/sample plot and finally converted into q/ha.

The observations were recorded for plant population/m^2, plant height (cm), tillers/plant, spike length (cm), number of grains/spike, 1,000 grain weight (g), and grain yield (q/ha). The data were analyzed using software O. P. Stat (Sheoran et al., 1998; Figure 1).

Results and discussion

The effect of trees on the understory crop is complex. Canopy of trees can exert positive, negative, and neutral effects on the production of plants depending on the local environmental conditions. In the current study, *Terminalia chebula* trees affected various growth and yield parameters such as plant population, plant height, spike length, tillers plant^{-1}, grains spike^{-1}, 1,000 grain weight, and grain yield of all varieties of *T. aestivum* under its canopy (Tables 1, 2). The presence of *Terminalia chebula* trees was

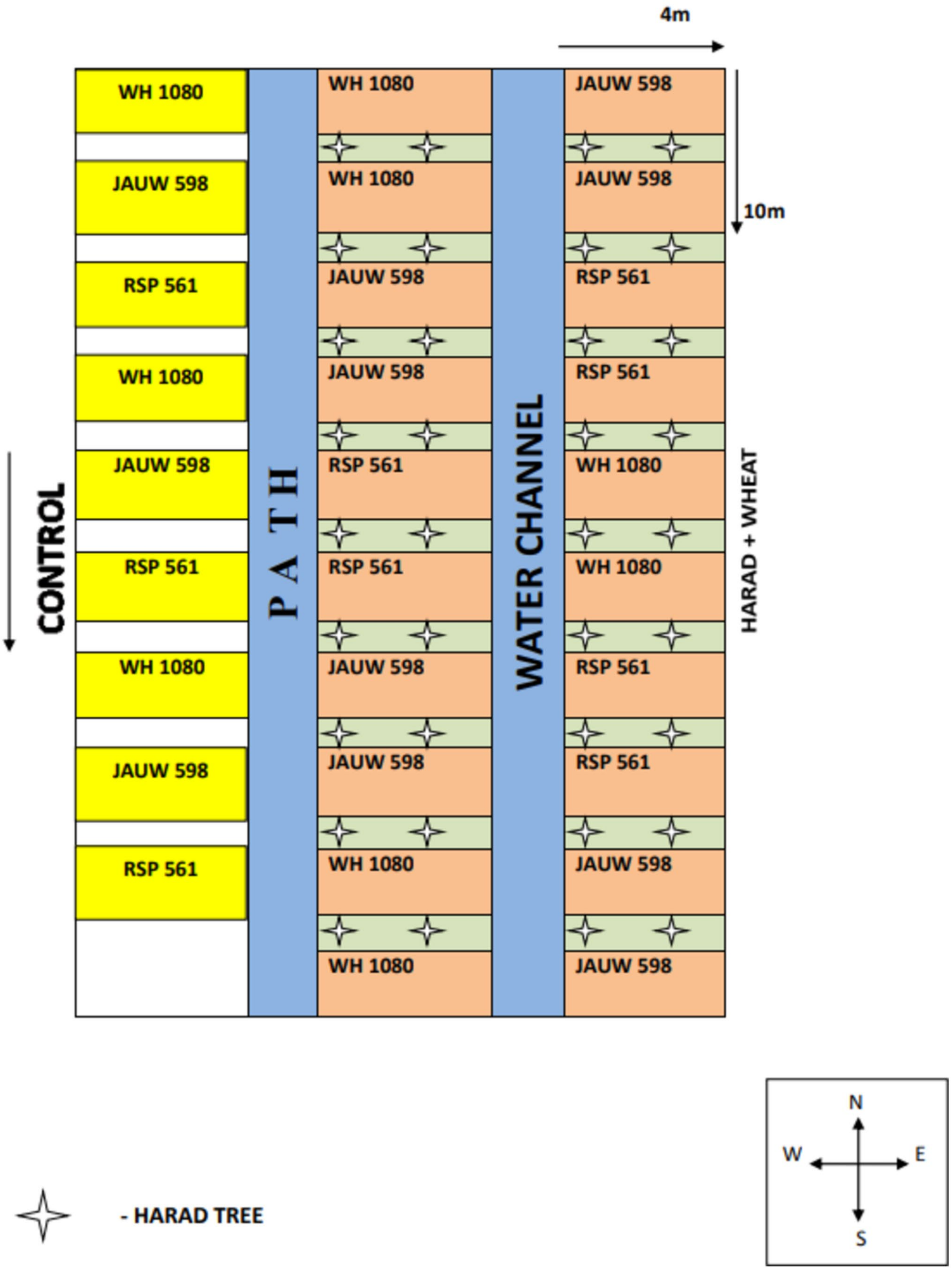

FIGURE 1
Layout plan of the field experiment under open and harad-based agroforestry system.

found to influence the growth parameters of wheat crops grown at two different distances in all three varieties. Reduction in these parameters was observed when wheat was grown in association with the tree at different distances as compared to the sole crop (control). This is probably attributed to the intense competition for resources such as water, nutrients, and solar radiation, especially at the tree–crop interface. A marked reduction in plant population was recorded in the wheat grown under tree canopy as compared to the wheat grown in open conditions (control). The maximum average plant population was recorded in control (47.00) and minimum (21.66) in T_5 (RSP-561, 0–1 m), which was statistically at par with treatments T_6 and T_7. It might be due to the immediate leaf shedding of trees after crop sowing, which leads to the reduced germination and the poor development of germinating seedlings. Leaf fall after the sowing acts as a barrier to germination and affects the availability of light and nutrition to developing seedlings; thus, their survival is affected. The plant population of wheat gradually increased with an increase in distance from the tree, which is clearly depicted in Table 1. The findings are in accordance with the findings reported by Chauhan et al. (2012) and Gawali et al. (2015) on wheat grown under different tree species. Reduction in plant height was mainly found at the closer distance of crop from the tree base (0–1 m) because at closer distance shading effect and competition for resources were more significant than the other distance D_2 (1–2 m) as well as in control. Maximum height (105.22 cm) was found in the variety WH-1080 (T_7) in an open condition whereas minimum (74.08 cm) in RSP-561 (T_5). Similar results were specified by Hossain et al. (2006) and Chauhan et al. (2012) in wheat grown under trees as well as in open conditions.

In the present study, tillers per plant were not affected by the shading effect of the tree. The maximum (7.36) tillers per plant were recorded in control treatment T_9 (RSP-561), and the minimum (6.49) was recorded in treatment T_4 (JAUW-598 at 1–2 m). Khan and Ehrenreich (1994) have also reported that the number of tillers per plant in wheat was not significantly affected when grown under *Acacia nilotica* trees. The environment has a significant effect on spike length; i.e., spike length was lower under trees than open. The maximum (13.91 cm) average spike length was recorded in treatment T_9, which was statistically at par with treatments T_5 (12.33 cm) and T_6 (13.04 cm). The minimum (10.12 cm) average spike length was recorded in treatment T_1. It might be due to lower production of photosynthates under low light conditions as the light intensity decreased under trees. Similarly, Gill et al. (2009), Dufour et al. (2013), Gawali et al. (2015), and Artru et al. (2017) have also reported that spike length was increased with an increase in distance from the tree base. On the other hand, the number of grains per spike was not affected by the presence of trees in all three varieties at both distances. These results are in accordance with the findings reported by Satyawali et al. (2018).

During the present study, we found that 1,000 grain weight of wheat varieties was significantly affected by the distance of the crop from the tree base. Maximum 1,000 grain weight was found in control as compared to the crop grown under tree canopy at two different distances. Some of the grains at closer distances

TABLE 1 Soil status of the experimental site.

Parameter	Test values	Method used
pH	7.90	1:2.5 soil water suspension electrode pH meter (Jackson, 1967)
EC(ds/m)	0.15	1:2.5 soil water suspensions with a systronic conductivity meter (Jackson, 1973)
Available Nitrogen (kg/ha)	251.30	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
Available Phosphorus (kg/ha)	16.10	Olsen et al. (1954)
Available Potassium (kg/ha)	162.70	Ammonium acetate method (Jackson, 1967)

TABLE 2 Effect of *Terminalia chebula* trees on various growth parameters of wheat.

Treatments	Parameters			
	Plant population/m^2	Plant height (cm)	Tillers/plant	Spike length (cm)
	Mean values	Mean values	Mean values	Mean values
T_1 (WH-1080, 0–1 m)	24.66	78.22	7.06	10.12
T_2 (WH-1080, 1–2 m)	25.66	84.23	7.22	11.02
T_3 (JAUW-598, 0–1 m)	27.33	79.80	6.91	10.32
T_4 (JAUW-598, 1–2 m)	35.33	82.44	6.49	11.14
T_5 (RSP-561, 0–1 m)	21.66	74.08	7.13	12.33
T_6 (RSP-561, 1–2 m)	38.66	80.18	7.17	13.04
T_7 (Sole WH-1080)	39.33	105.22	7.01	11.48
T_8 (Sole JAUW-598)	47.00	97.56	7.12	12.02
T_9 (Sole RSP-561)	42.00	94.08	7.36	13.91
$C.D_{0.05}$	15.54	10.32	NS	2.01
SE(m)±	5.14	3.41	0.33	0.66

TABLE 3 Effect of *Terminalia chebula* trees on various yield parameters of wheat.

Treatments	Parameters		
	Number of grains/spike	1,000 grain weight (g)	Grain yield (q/ha)
	Mean values	Mean values	Mean values
T_1 (WH-1080, 0–1 m)	29.36	34.73	24.72
T_2 (WH-1080, 1–2 m)	31.01	35.02	30.23
T_3 (JAUW-598, 0–1 m)	29.69	30.34	22.69
T_4 (JAUW-598, 1–2 m)	32.03	34.29	32.24
T_5 (RSP-561, 0–1 m)	29.25	35.57	22.15
T_6 (RSP-561, 1–2 m)	30.90	38.79	37.30
T_7 (Sole WH-1080)	32.80	39.82	35.72
T_8 (Sole JAUW-598)	30.48	39.04	40.25
T_9 (Sole RSP-561)	33.62	41.25	42.46
$C.D_{0.05}$	NS	4.63	8.31
SE(m)±	1.51	1.53	2.74

were shriveled and smaller in size. The possible reason could be the lesser availability of moisture, light, and nutrients for proper growth and development of the wheat crop; in addition, shading results in an appreciable decrease in a number of grains per spike and grain weight. Similar results were reported by Gill et al. (2009), Chauhan et al. (2012), Dufour et al. (2013), and Artru et al. (2017).

The yield of the wheat varieties was better in the open than under the *Terminalia chebula* trees. Maximum (42.46 q ha^{-1}) grain yield was recorded in treatment T_9, which was at par with treatment T_8 (40.25 q ha^{-1}), T_6 (37.30 q ha^{-1}), and T_7 (35.72 qha^{-1}). Minimum (22.15 qha^{-1}) grain yield was recorded in treatment T_5. The effect of distance and shade on the yield parameters was significant and absolutely clear. The maximum reduction in grain yield was obtained at a distance of 0–1 m (D_1) as compared to a distance of 1–2 m (D_2) from the tree base, and maximum yield was recorded in open conditions. It might be due to the effect of shade on the crop. The grain yield was lowest near the trees and gradually increased with distance from the trees. The reduction in the yield of intercrop due to the presence of trees may be attributed to the pattern of canopy spread resulting in variation in light interception and competition of the tree roots for nutrients and moisture (Table 3). Reduction in the grain yield of wheat in all the varieties at different distances is well supported by the findings reported by Hossain et al. (2006), Gill et al. (2009), Chauhan et al. (2012), Dufour et al. (2013), Gawali et al. (2015), Artru et al. (2017), Bisht et al. (2017), Satyawali et al. (2018), Yadav et al. (2018), and Kumar et al. (2019).

Conclusion

From the present study, it is concluded that wheat can be grown successfully at a distance of 1–2 m from the base of *Terminalia chebula* trees. RSP-561 is the suitable wheat variety for intercropping in the harad orchard on the basis of a minimum yield reduction of 12.15% at a distance of 1–2 m from the tree base compared to WH-1080 and JAUW-598.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

AK: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Writing – original draft, Writing – review & editing. MG: Project administration, Supervision, Validation, Writing – review & editing. LG: Project administration, Validation, Writing – review & editing. SK: Project administration, Supervision, Validation, Writing – review & editing. PC: Project administration, Supervision, Validation, Writing – review & editing.

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Conflict of interest

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