Effect of windbreaks (*Casuarina equisetifolia*L.) on productivity of paddy in South Gujarat

ABSTRACT

The intentional integration of trees into an agroecosystem results in agroforestry practices such as windbreak, which simultaneously help the economy, the environment, and society. It is a crucial tool for safeguarding agricultural land and boosting crop productivity. An investigation was therefore conducted to determine the impact of windbreaks (*Casuarina equisetifolia* L.) on paddy productivity in South Gujarat. In the current study, we found that environmental competition caused paddy growth and production to decrease close to the Casuarina windbreak. The impact of the windbreaks on paddy growth and yield became positive, and the continuously increased distance from the windbreaks reached its maximum at 17 m and then gradually decreased. The wind velocity maximum close to windbreaks exhibits an opposite tendency, decreasing continually to a minimum at a distance of 17 meters from the windbreaks before increasing once again. In addition, this system's net returns and benefit-cost ratio were noticeably higher than those of open fields. In contrast to the control, the pH of the soil beneath the windbreak was reported to be considerably closer to neutral, while electrical conductivity was reduced. The impact of windbreaks was found to considerably increase soil organic carbon, accessible nitrogen, phosphorus, and potassium as compared to control. According to the study's overall findings, windbreak-protected paddy fields perform noticeably better than open ones.

Keywords: Windbreak, Casuarina, Paddy, Growth, Yield, Crop productivity, Soil Properties

Introduction :

Technically, the term 'Windbreaks' refers to the narrow stripe (few rows) of trees and/or shrubs planted around the homestead, farmland, and feedlot for protecting the advancing wind (Baer 1989; Chundawat and Gautam 1993). Windbreaks originally referred to the planting of trees intended to shield a farmhouse or feedlot from the wind (Baer 1989). Gradually, over a period of time, people started using these words interchangeably (Nair 1985, Takle 2005). Smith *et al.* (2021) consider windbreaks itself as a single system and alternately called hedgerows, shelterbelts, living snow fences, or vegetated environmental buffers based on specific purposes. Climate is the factor with the greatest impact on agricultural productivity. It is therefore not surprising that the practice of intentional microclimate modification is as old as the practice of agriculture itself. In particular, windbreaks providing shade and shelter have long been used as a tool to create a more benign and productive microclimate. Windbreaks have the potential to greatly increase animal, pasture, and agricultural output.Thus, planting tree windbreaks is seen to be a good approach to slow down land deterioration and potentially boost agricultural output. The main effect of a tree windbreak is to provide shelter – *i.e.*, a windbreak alters the mean wind speed, wind direction, and turbulence of the airflow (Cleugh 1998, Dhyani *et al.* 2016).

One of the main causes of the decline in rice quality and production is lodging. Plants that are unable to stand straight are said to be lodged, and this can result in a loss of production as the combine is unable to gather the grain from the plants. A large portion of the plant is destroyed by severe lodging, which lowers grain output, photosynthetic capacity, and harvesting efficiency. In addition to the direct impacts of wind and rain, an overabundance of soil nitrogen can also result in crop lodging (Lang *et al.* 2012). Casuarina windbreak trees, when planted on the edges of agricultural areas, have demonstrated significant potential in reducing wind speed and mitigating harm to cash crops. It is a multipurpose tree species amenable for agro and farm forestry system and also as windbreaks (Parthiban *et al.* 2014). Thus, the goal of the current study is to ascertain how casuarina windbreaks affect the economics and production of paddy crops.

MATERIALS AND METHODS

Study area: The experiment was conducted during*kharif* season of 2020 and 2021 at PCP farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari, South Gujarat.Geographically it is located at 20.95° N latitude and 72.93° E longitude with an elevation of 11 m above mean sea level (AMSL). This area is typically characterized by humid and warm monsoon with rainfall of about 1500-1800mm, moderately cold winter, and fairly hot and humid summer. The average annual temperature is 27.1 °C.

Methods: For the assessment of windbreaks effect on paddy, *Oryza sativa* (Variety: GNR-3) seedling was transplanted in line at 45 cm leeward side of*Casuarina equisetifolia*windbreak(15 years old single raw) and in open condition. This experiment was designed in a randomised block design with nine treatments (distance from windbreaks) viz., T_0:-At distance 2 m from wind break, T_1:- At distance 5 m from wind break, T_2:- At distance 8 m from wind break, T_3:- At distance 11 m from wind break, T_4:- At distance 14 m from wind break, T_5:- At distance 17 m from wind break, T_6:- At distance 20 m from wind break, T_7:- At distance 23 m from wind break and T_8:- without windbreaks field, and three replications. Required cultural operations carried out during the whole experiment.Wind velocity (km/hr) was measured at monthly interval in each treatments of distance from the windbreak by using digital wind anemometer. Essential observations of paddy were recorded as needed to fulfil the objectives.

Characters of windbreak: Inpresentstudy the windbreak was single raw of 15 years old *Casuarina equisetifolia*. Its average height was 22 m and diameter 28 cm at breast height, Crown length 18 m and Crown width (North-South 6.3 m East-West 6.2 m).

Soil analysis: After the harvest of paddy soil samples were collected from 0 to 15 cm depth of alltreated plot for Soil physico-chemical properties analysis and analyzed in soil science laboratory, Department of natural resource management, College of Forestry, NAU, Navsari. Different standardmethods were used for soil analysis which given by different scientist for EC, soil pH and organic carbon (Jackson 1967), available N (Subbiah and Asija 1956), P_2O_5 (Singh*et al*.2005) and K_2O (Jackson 1967).

Statistical Analysis: Recorded two-year average dataof variables were analysed and compared by analysis of variance (ANOVA) of randomised block design with the critical difference (CD, $p < 0.05$) (Panse and Sukhatme 1995).

RESULTS AND DISCUSSION

Effect of windbreaksongrowth and yield

Growth and yield characteristics paddy are the most crucial factors to take into account when estimating crop production. The pooled analysis from the two years (2020 and 2021) of growth and yield variables are presented in Table 1. Results show that there was a significant effect of wind break (*Casuarina equisetifolia* L.) on productivity of paddy. Plant height (97.34 cm), number of tillers per plant (11.17), total fresh weight plant (17,799 kg ha^{-1}), dry straw weight (6,577 kg ha^{-1})and grainyield (4,103 kg ha^{-1}) were significantly higher in the treatment T_5 (17 m far from windbreaks) due to the lower the wind velocity (3.32 km hr^{-1}) as compared to other treatments. Because of the wind breaks shade, treatment T_0 (2 m far from windbreaks) reported minimum plant height (83 cm), tillers per plant (8.17), total fresh weight plant (12,315 kg ha^{-1}), dry straw weight (4,855 kg ha^{-1}) and grain yield (3,101 kg ha^{-1}). However, results indicate that the increasing the distance from the windbreak increase the crop productivity. Kort (1988) provided support for this finding, revealing that windbreaks significantly enhance output for winter wheat (*Triticum aestivum*) by 23%, soybeans (*Glycine max*) by 15%, and maize (*Zea mays*) by 12%. Whereas soybeans responded to windbreaks in the most favorable way.Similarly, result was observed in plant fresh weight of rice was increased by sheltering (Monette and Stewart 1987). North side and narrow windbreaks compensated for the footprint of the windbreaks 71% of the time, while south side and wider windbreaks only compensated for the windbreaks footprint 38% of the time (Osorio *et al*. 2019). According to Liu et al. (2022), the environment competition between the shelterbelt and corn caused the corn yield to decrease close to it. However, after 1.2 H, the shelterbelt's effect on corn yield turned positive, growing steadily until it reached a maximum at 3.5 H before gradually declining.Similar results were also observed by Sirohi*et al*. (2022), Campi *et al*. (2009), Sudmeyer and Scott (2002).

Table 1: Effect of wind breaks (*Casuarina equisetifolia* L.) on crop productivity

Treatments	**Plant height (cm)**	**Number of tiller per plant**	**Total fresh wt. plant (kgha^{-1})**	**Dry straw weight (kgha^{-1})**	**Grain weight (kgha^{-1})**
T_0 (2 m)	83.00	8.17	12,315	4,855	3,101
T_1 (5 m)	85.00	8.67	14,450	5,101	3,804
T_2 (8 m)	88.17	9.50	14,564	5,096	3,916
T_3 (11 m)	90.17	9.67	15,188	5,434	4,024
T_4 (14 m)	95.50	10.50	17,143	6,021	4,069
T_5 (17 m)	97.34	11.17	17,799	6,577	4,103
T_6 (20 m)	89.17	10.00	15,754	5,897	4,003
T_7 (23 m)	84.17	8.50	13,725	4,818	3,498
T_8 (Control)	89.17	9.00	15,170	5,230	4,024
SEM (±)	3.184	0.317	444.47	280.68	244.19
CD @ 5%	9.54	0.912	1332.14	841.23	731.86
CV%	6.19	5.80	5.09	8.92	11.02

Effect of windbreaks on economic

Estimated the economics of the systems reported highest net returns Rs. 40,619 and benefit cost ration 0.61 were generated from treatment T_5 (At distance 17 m from wind break) as compared to other treatments. Whereas,treatment T_8 Without windbreaks (open field) has net returns Rs. 34,749 and benefit cost ration 0.52(Table 2). Several studied were supported by different researches. Brandle *et al*. (1984) studied field windbreaks systems that occupy between 5 and 6% of the crop field provide positive economic returns to producers based entirely on the increased yields found in sheltered areas.An interactive computer model was created by Brandle and Kort (1991) to assess the financial benefits to grain growers who provide windbreak protection for their crops.Grala and Colletti (2003) Fast-growing, long-lasting windbreaks were more advantageous economically. They stressed that investing in a windbreak system is a long-term commitment. Helmers and Brandle (2005) they compared to the net return for unprotected maize and soybean, an ideal spacing of 13 H enhanced net returns by 7.6% for corn and 9.2% for soybeans on the windbreaks investment.

Table 2: Gross return, Net return and BCR

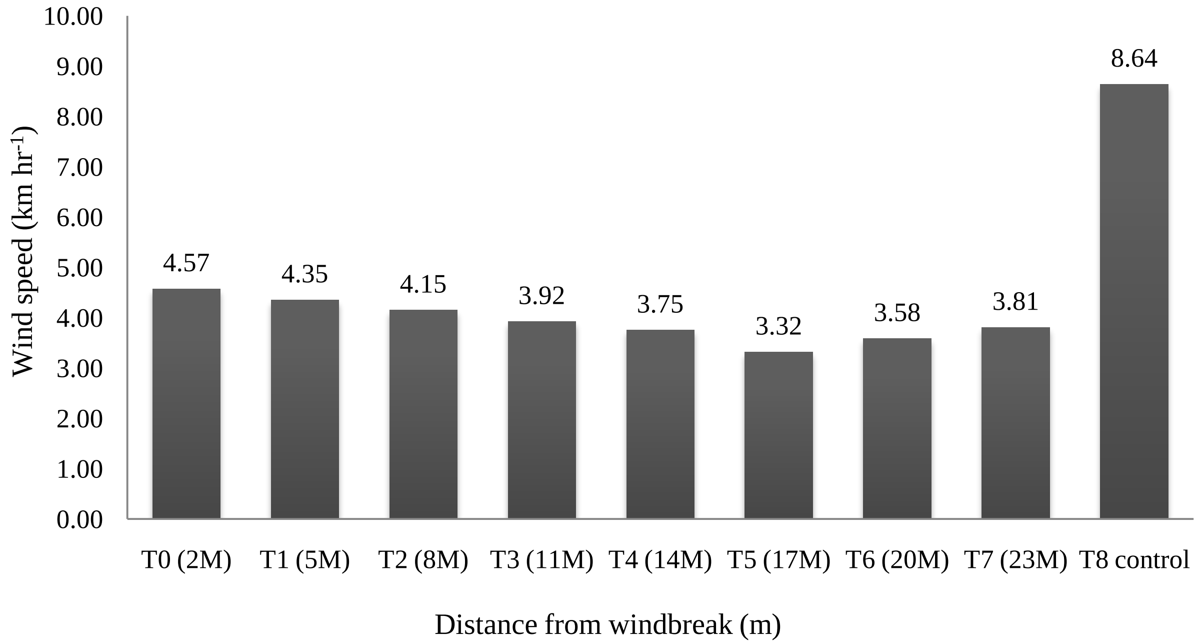
Treatments	Grain yield (kg/ha)	Straw yield (kg/ha)	Cost of cultivation	Gross Realization (Rs./ha)	Net Realization (Rs./ha)	BCR
T_0 (2 m)	3,101	4,055	66,716	79,314	12,598	0.19
T_1 (5 m)	3,804	4,801	66,716	96,688	29,972	0.45
T_2 (8 m)	4,016	4,895	66,716	1,01,469	34,753	0.52
T_3 (11 m)	4,082	4,934	66,716	1,02,991	36,275	0.54
T_4 (14 m)	4,143	4,921	66,716	1,04,227	37,511	0.56
T_5 (17 m)	4,315	4,777	66,716	1,07,335	40,619	0.61
T_6 (20 m)	4,003	4,997	66,716	1,01,553	34,837	0.52
T_7 (23 m)	3,513	4,917	66,716	90,983	24,267	0.36
T_8 (Control)	3,960	5,230	66,716	1,01,465	34,749	0.52

Note: Straw rate @ Rs. 3.5 $kg^{-1}$and Grain rate @ Rs. 21kg^{-1}

Effect of windbreaks on wind velocity (km hr^{-1})

Every month, the anemometer was used to measure the wind speed. Figure 1 shows average statistics on how various treatments affect wind velocity visually. Results are indicating that wind speed significantly affected due to the different treatments.Observed data showed that among the different treatments, significantly higher wind velocity (8.64 km hr^{-1}) recorded in open treatment (without windbreak) as compared leeward side of windbreak. In leeward side of windbreak, from the base of windbreak to increase the distance 2 m (T_0) to 17 m (T_5) wind velocity continuously decrease, T_5 (17 m) shows minimum wind velocity (3.32 km hr^{-1}) after that continually increased wind velocity. Similar result found by Foereid*et al*. (2002) that wind speed was reduced; the ratio *u*/*u*0 was found to be 0.37 at the point closest to the windbreaks. At 35m from the windbreaks*u*/*u*0 reached 0.86 and did not increase further. This seems to indicate that the equipment measured significantly lower values than the reference; in particular, it had a higher 0-threshold. The same study also supported by (Mulheran and Bradley 1977, Brenner *et al*. 1995, Zhang *et al.* 1995, McNaugthon1988).

Figure 1: Effect of wind breaks (*Casuarina equisetifolia* L.) on wind velocity (km hr^{-1})



Effect of windbreakson soil physico-chemical properties

Soil fertility is a major factor in crop development and yield. Numerous elements, including organic matter, fertilizer, climate, and location, affect soil fertility. A windbreak can enrich the soil with organic matter from the roots of nearby trees. In present study the effect of windbreak on soil properties were analyzed and presented in Table 3. Presented data revealed that the different distances from windbreak significantly affect the soil properties. The experimental results were indicating that pH of soil was found significantly near neutral range as compare to control (7.73). Soil EC 1:2.5 (dSm^{-1}) showed that under effect of windbreaks EC was decreased in compare to control (0.34). Whereas, the soil fertility parameters soil organic carbon (0.68 %), available nitrogen (234.46 kg ha^{-1}), phosphorous (75.75 kg ha^{-1}) and potash (398.07 kg ha^{-1}) were recorded significantly higher in T_0 treatment (2 m from windbreak) as compared to others treatments. Whereas lowest recorded in control (T_8). The results indicate that the increasing the distance from the windbreak decreased the soil physio-chemical properties. Same study carried out by Lalozaei*et al.* (2016) that with the construction of the two windbreaks, electro conductivity, organic matter, calcium, potassium, sodium and carbon to nitrogen ratio had a significant (95%) increase compared to the control region.Chauhan *et al.* 2010 reported that after 6 years of poplar planting, organic carbon increased in soil than pure wheat crop. Sirohi*et al.* (2022) carried out that the highestavailable soil N (365.2 kg ha^{-1}), P (19.7 kg ha^{-1})and K (357.3 kg ha^{-1}) were recorded near the tree lineat a distance of 2 m.Similar study carried out by (Shah and Kalra 1970, Chang*et al*. 2021).

Table 3:Effect of windbreaks on soil physio-chemical propertiesof paddy field

Treatments	Soil pH	Soil EC (dS/m)	Soil OC (%)	Soil Available Nitrogen (kg/ha)	Soil Available Phosphorous (kg/ha)	Soil Available Potash (kg/ha)
T_0 (2 m)	7.46	0.19	0.68	234.46	75.75	398.07
T_1 (5 m)	7.37	0.26	0.56	230.54	72.35	370.13
T_2 (8 m)	7.52	0.27	0.53	229.50	71.44	349.75
T_3 (11 m)	7.66	0.27	0.50	226.22	69.55	344.82
T_4 (14 m)	7.68	0.28	0.49	225.00	68.82	340.15
T_5 (17 m)	7.68	0.28	0.48	224.12	68.55	339.17
T_6 (20 m)	7.69	0.29	0.48	223.30	67.52	339.05
T_7 (23 m)	7.69	0.30	0.47	220.54	66.96	336.12
T_8 (Control)	7.73	0.34	0.48	211.45	58.70	322.27
SEM (±)	0.026	0.013	0.019	5.581	6.749	10.24
CD @ 5%	0.08	0.04	0.06	16.72	18.97	30.725
CV %	0.60	8.57	6.43	4.30	17.29	5.08

Based on the above discussion, it can be concluded that the experiment demonstrated the considerable effects of windbreaks at varying distances from the windbreak on paddy growth and yield. The impact of windbreaks is evident at a distance of 17 meters from them, as evidenced by the notable increase in straw height, the number of tillers per plant, the total weight of fresh plants, dry straw weight of paddy, and dry grain weight of rice. Beyond that point, however, growth and paddy production begin to decline. It is evident that from 2 to 17 meters from the wind break, the wind velocity dramatically decreased before beginning to increase. In addition to improving the qualities of the soil, windbreaks have a significant effect on soil health.

REFERENCES

Baer N W. 1989. Shelterbelts and Windbreaks in the Great Plains. *Journal of Forestry* **87**: 32-36.

Brandle J R and Kort J. 1991. WBECON: A windbreaks evaluation model 1. Comparison of windbreaks characteristics. p. 129–131. *In* Finch S and Baldwin C S (Eds) Windbreaks and agroforestry. 3rd International Symposium on Windbreaks and Agroforestry. June 1991, Ridgetown College, Ridgetown, ON, Canada.

Brandle J R, Johnson B B and Dearmont D D. 1984. Windbreaks economics: The case of winter wheat production in eastern Nebraska. *Journal of Soil and Water Conservation* **39**: 339–343.

Brenner A J, Jarvis P G and van den Beldt R J. 1995. Windbreaks crop interactions in the Sahel. 1. Dependence of shelter on field conditions. *Agricultural and Forest Meteorology* **75**: 215–234.

Campi P, Palumbo A D and Mastrorilli M. 2009. Effects of tree windbreaks on microclimate and wheat productivity in a Mediterranean environment. *European Journal of Agronomy***30**: 220–227.

Chang X, Sun L, Yu X, Liu Z, Jia G, Wang Y and Zhu X. 2021. Windbreaks efficiency in controlling wind erosion and particulate matter concentrations from farmlands. *Agriculture, Ecosystems and Environment* **308**: 107269.

Chauhan S K, Sharma S C, Beri V, Ritu, Yadav S and Gupta N. 2010. Yield and carbon sequestration potential of wheat (*Triticum aestivum*) -poplar (*Populus deltoides*) based agri-silvicultural system. *Indian Journal of Agricultural Sciences* **80**(2): 129–35.

Chundawat B S and Gautam S K. 1993. Textbook of agroforestry. Oxford & IBH.

Cleugh H. 1998. Effects of windbreaks on airflow, microclimates and crop yields. *Agroforestry Systems***41**(1):55–84.

Dhyani S K, Asha Ram and Dev I. 2016. Potential of agroforestry systems in carbon sequestration in India. *Indian Journal of Agricultural Sciences***86** (9): 1103–12.

Foereid B, Rasmus B, Mogensena V O and Porter J R. 2002. Effects of windbreaks strips of willow coppice—modelling and field experiment on barley in Denmarka. *Agriculture, Ecosystems and Environment***93**: 25–32.

Grala R K and Colletti J P. 2003. Estimates of additional maize (*Zea mays*) yields required to offset costs of tree windbreaks in the mid-western USA. *Agroforestry Systems***59**:11–20.

Helmers G A and Brandle J. 2005. Optimum windbreaks spacing in Great Plains agriculture. *Great Plains Research: A Journal of Natural and Social Sciences***15**: 179–198.

Jackson M L. 1967. Soil chemical analysis. Prentice Hall of India Pvt. Ltd., New Delhi, pp.183-226.

Kort J. 1988. Benefits of windbreaks to field and forage crops. *Agriculture, Ecosystems and Environment***22/23**: 165-190.

Lalozaei A, Ghaleno M D and Ebrahimi M. 2016.Effect of the tree wind breaksers of Tamarix and Eucalyptus on some physical and chemical properties of soil in Hamoon Plain. *Journal of Watershed Engineering and Management***7**(4): 536-542.

Lang Y, Yang X, Wang M and Zhu Q. 2012. Effects of lodging at different filling stages on rice yield and grain quality. *Rice Science***19**(4): 315-319.

Liu Y, Li H, Yuan F, Shen L, Wu M, Li W and Guan D. 2022. Estimating the impact of shelterbelt structure on corn yield at a large scale using Google Earth and Sentinel 2 data. *Environmental Research Letters* **17:** 044060.

McNaugthon K G. 1988. Effects of windbreaks on turbulent transport and microclimate. *Agriculture, Ecosystems and Environment***22/23**: 17–39.

Monette S and Stewart K A. 1987.The effect of a windbreak and mulch on the growth and yield of pepper (*Capsicum annuum* L.). *Canadian Journal of Plant Science***67**: 315-320.

Mulheran P J and Bradley E F. 1977. Secondary flow in the lee of porous shelterbelts. *Boundary-Layer Meteorology***12**: 75–92.

Nair P K R. 1985. Classification of agroforestry systems.

Osorio R J, Barden C J and Ciampitti I A. 2019. GIS approach to estimate windbreaks crop yield effects in Kansas–Nebraska. *Agroforestry Systems* **93**: 1567–1576.
Panse V G and Sukhatme P V. 1985. In: Statistical Methods for Agricultural Workers. Fourth enlarged edition revised by Sukhatme P V and Amble V N Published by Sat Prakash, Under-Secretary for ICAR, New Delhi. India.
Parthiban K T, Rohini A and Anandhi V. 2014. Impact of Casuarina wind breaks – Case Study, At Fifth International Casuarina Workshop on 3rd to 7th February, 2014, Mamallapuram, Channai, India.
Shah S R H and Kalra Y P. 1970. Nitrogen uptake of pants affected by windbreaks. *Journal of Plant and Soil* **33**: 573-580.
Singh D, Chhonkar P K and Dwivedi B S. 2005. Manual on soil, plant and water analysis. Westville Publishing House, New Delhi, India.
Sirohi C, Bangarwa K S, Dhillon R S, Chavan S B and Handa A K. 2022. Productivity of wheat (*Triticum aestivum* L.) and soil fertility with poplar (*Populus deltoides*) agroforestry system in the semi-arid ecosystem of Haryana, India. *Journal of Current Science* **122** (9): 1072-1080.
Smith M M, Bentrup G, Kellerman T, MacFarland K, Straight R and Ameyaw L. 2021. Windbreaks in the United States: A systematic review of producer-reported benefits, challenges, management activities and drivers of adoption. *Agricultural Systems* **187**: 103032.
Subbiah B V and Asijah G L A. 1956. A rapid procedure for the estimation of available nitrogen in soils. *Current Science* **25**: 259-260.
Sudmeyer R and Scott P. 2002. Characterization of a windbreaks system on the south coast of Western Australia. 1. Microclimate and wind erosion. *Animal Production Science* **42**(6):703–715.
Takle E S. 2005. Windbreaks and shelterbelts. Encyclopedia of Soils in the Environment.
Zhang H, Brandle J R, Meyer G E and Hodges L. 1995. The relationship between open wind speed and wind speed reduction in shelter. *Agroforestry Systems* **32**: 297–311.