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Effect of different spacings of eucalyptus plantation on biomass production of wheat cultivars in Northern India

Vinita Bisht, Shalini Purwar, Devendra Kumar, Brajesh Kumar and Vijay Upadhayay

Abstract
The experiment was carried out in the research farm of Department of Forestry, CCS Haryana Agricultural University, Hisar, Haryana. Treatments were made in an on going, already established 7 and 8 years eucalyptus plantation experiment with different wheat cultivars, adapted to three levels of spacings viz. 3 × 3 m, 6 × 1.5 m and 17 × 1 × 1 m. In this study the effect of different spacings of eucalyptus on growth, yield attributing parameters and production of wheat cultivars in semi-arid region of Haryana. Among wheat cultivars, variety HD-2967 produced significantly higher growth and yield in paired row (17×1×1 m) planting than planting at 6×1.5 m and 3×3 m during both the year of experimentation. Growth and biomass attributing parameters of wheat varieties (WH-1105, WH-542, HD-2967, HD-943 and DPW-621-50) reduced significantly under different spacings of eucalyptus in comparison to sole crop (devoid of tree). Paired row (17 × 1 × 1 m) planting of eucalyptus was found to be best *w.r.t.* wheat growth and biomass production followed by 6 × 1.5 m and 3 × 3 m. Among wheat varieties, HD-2967 was observed shade and stress tolerant variety.

Keywords: biomass production, cultivars, eucalyptus, shade tolerant, yield

Introduction
The pressure from increasing population and urbanization, coupled with land degradation and climate change are the major causes for food insufficiency in developing world. Among different approaches to combat this problem, woody perennial based production systems has the great potential. Historically, agroforestry in India involved two distinct pathways, *viz.*, growing food crops in the forests and establishing tree-crop production systems on arable lands. Agroforestry is a land use system that increases livelihood security and reduces vulnerability to climate and environmental changes. It requires optimization and sustained management of available resources in a given area rather than their over exploitation (Dhyani *et al.*, 2009) [3]. Agroforestry, growing of multipurpose trees along with agricultural crops is one of the key paths towards the prosperity of poor people suffering from hunger, malnutrition, abject poverty and deterioration of the environment in the areas that have been bypassed by the Green revolution (Garrity, 2004) [4]. The increase in biomass production may be attributed to enhanced rate of photosynthesis and higher fixation of carbon and its allocation to plant components (Bhatt *et al*., 2010). Physical damage at chloroplast level, eventually reducing the photosynthetic capacity (Ravi *et al*., 2019) [13]. Agroforestry systems not only arrest land degradation but also improve site productivity through interactions among trees, soil, crops, and livestock (Kumar, 2006) [7]. Besides, agroforestry is capable of conserving natural resources under different agro-climatic regions and is the only option to increase the forest/ tree cover from the present less than 25% to 33% in the country. Realizing the importance of agroforestry Government of India has pronounced a National Agroforestry Policy (2014) and directed the stakeholders to speedy implementation. There is a growing interest among farming communities to integrate fast growing multipurpose trees in agroforestry systems to obtain early and good economic returns. *Populus deltoides,* is one such promising species recognized as important tree component in agroforestry system to prevent land degradation and obtain biological production on sustainable basis (Pandey, 2007) [10]. Due to its fast growth, less competition with associated crops and pruning tolerant nature, giving good economic returns in short rotation *i.e.* 5-7 years with easy availability of bank loans, have become the most popular tree species for planting under agro-forestry systems by farmers after

1980 in Haryana, Punjab, Uttar Pradesh, Himachal Pradesh and Arunachal Pradesh states.

Wheat (*Triticum aestivum* L.) is the most important food crop is intercropped throughout its rotations. Farmers are cultivating agriculture crops throughout the harvesting period and consider poplar trees as assured wealth of their future needs. The spacing for poplar plantation is generally kept at 5 m × 4 m or 5 m ×5 m, which allows tractor ploughing and other cultivation operations without any difficulty. Since no proper spacing as yet has been standardized in different agroforestry systems to avoid the adverse effect of trees on growth and yield of intercrops, therefore, there is a need to determine proper tree spacing for intercropping in agroforestry systems. There is need to refine the cultural practices to grow wheat under the block plantation of poplar. The present study was therefore conducted to evaluate the performance of five wheat varieties for growth and biomass production under different spacings of poplar based agroforestry system.

Materials and Methods

Experimental site

The present study was conducted during 2013-14 and 2014-15 in an already established 7 and 8 years poplar plantation spaced at 3 × 3 m, 6 × 1.5 m and 17 × 1 × 1 m at research farm of Department of Forestry, CCS Haryana Agricultural University, Hisar, Haryana (29^0 $09^{'}$ N latitude and 75^0 $43^{'}$ E longitude at an elevation of 215 m above mean sea level), situated in the arid region of North-Western India. The climate is subtropical-monsoonic with an average annual rainfall of 350-400 mm, 70-80 per cent of which occurs during July to September. The summer months are very hot with maximum temperature ranging from 40 to 45 ºC in May and June whereas, December and January are the coldest months (lowest January temperature as low as 0 °C). The site received 447.9 mm rainfall during 2014-15.

Field experimentation

The wheat varieties WH-1105, WH-542, HD-2967, HD-943 and DPW-621-50 were sown during the first week of November keeping a row to row distance of 22.5 cm with a seed rate of 100 kg/ha. In the nearby field, all of five wheat varieties were sown as control (without tree). In this experiment the recommended dose of fertilizer (150 kg N, 60 kg P_2O_5 and 60 kg K_2O ha^{-1}) was applied. The whole amount of P and K and half N was applied at the time of sowing. The remaining N through urea was top dressed at Crown Root Initiation (CRI) stage. Same procedure was followed during 2014-15. Wheat crop was estimated in terms of growth and yield parameters {plant height, dry matter accumulation, biological yield, harvest index (%) and attraction index (%)} by quadrate method at different time of plant growth and at harvest. The yield of the produce (biological yield) was extrapolated to be expressed in t/ha. Data obtained during the course of this investigation, was analysed by using factorial randomized block design. The differences among treatments were compared by applying test of significance at 5% probability (Panse and Sukhatme, 1989) [11].

Results and Discussion

Plant height

Among different spatial arrangements of eucalyptus (3 × 3 m, 6 × 1.5 m and 17 × 1 × 1 m), the plant height of different wheat varieties differed significantly at different time intervals of growth (Table 1). The performance of wheat varieties for plant height was found best with paired row planting (17 × 1 × 1 m) followed by 3 × 3 m and 6 × 1.5 m spacing of eucalyptus. HD-2967 variety of wheat was found more tolerant to shade which was reflected by its maximum height at different stages of growth under various spacings of eucalyptus followed by DPW-621-50, HD-943 and WH-542 during both the years of experimentation. However, variety WH-1105 was observed to be the most sensitive to shade which showed stunted growth and exhibited lesser plant height at different stages of growth under various spacings of eucalyptus during both 2013-14 and 2014-15. All the tested wheat varieties showed significantly lesser plant height under various spatial arrangements of eucalyptus based agroforestry system in comparison to control (without tree) from 30 DAS to 120 DAS (Table 1). The findings of present study are in agreement with the results of Kaur *et al.* (2010) [6] who reported that plant height of wheat was significantly more in sole crop than the intercropping with poplar. This might be due to the difference in the light intercepted by the sole wheat crop and poplar-intercropped plots less in the months of December to February, but it increased considerably after mid of March. Therefore, reduced light intensity in poplar based agroforestry system decreased the photosynthetic efficiency of crops resulting in poor growth performance. Poor performance of wheat crop was caused by decreased photosynthetic efficiency as a result of reduced light intensity in poplar based agroforestry system (Chauhan and Dhiman, 2007; Rani *et al.*, 2011; Chauhan *et al.*, 2012) [2, 12, 1].

Dry matter accumulation

The dry matter accumulation by different wheat varieties also differed significantly among different spacings of eucalyptus (Table 2). The performance of wheat varieties for dry matter accumulation was found best with paired row planting (17 × 1 × 1 m) followed by 6 × 1.5 m and 3 × 3 m spacing of eucalyptus. Among different wheat varieties, the highest dry matter accumulation was observed in wheat variety HD-2967 and it followed the order: WH-542 > DPW-621-50 > HD-943 > WH-1105 in paired row planting (17 × 1 × 1 m) than planting at 6 × 1.5 m and 3 × 3 m spacing at different stages of growth during 2013-14 and 2014-15. The variety WH-1105 accumulated lowest dry matter under different spacings of poplar from 30 DAS to 120 DAS however; it attained maximum dry matter under control during both 2013-14 and 2014-15. Present findings are in close agreement with the findings of Kumar and Rajput (2005) [8] who reported that total dry matter accumulation differed significantly among wheat varieties under poplar based agroforestry system and under control. They further reported that variety UP 2338 recorded significantly more dry matter over all other varieties (WH 542, Raj 3077, PBW 154, HD 2285, HD 2329, UP 2113, UP 2003, PBW 226, UP 262 and PBW 343). In intercropping system, competition for light has been reported to have a large influence than either moisture or nutrients and dry mater production bears an almost linear relationship with the quantum of intercepted energy (Monteith, 1977) [9]. More light intensity in control increased the photosynthetic efficiency of crops resulting in better growth as reported by Wassinck (1954) [15]. The crop growth is mainly affected by light and nutrient availability. Sharma *et al.* (2000) [14] also reported that close spacing of poplar inhibit the crop growth of wheat.

Table 1: Plant height of wheat varieties during different time intervals of growth under different spacings of eucalyptus

Spacing (m)	2013-14 HD-2967	DPW-621-50	HD-943	WH-542	WH-1105	Mean	2014-15 HD-2967	DPW-621-50	HD-943	WH-542	WH-1105	Mean
30 DAS												
3 × 3	15.7	13.3	12.2	10.3	9.2	12.1	14.8	12.6	11.6	9.8	8.7	11.5
6 × 1.5	19.7	17.3	16.1	14.2	12.6	16.0	18.6	16.4	15.3	13.5	12.0	15.2
17 × 1 × 1	24.2	22.4	21.3	18.9	16.2	20.6	22.9	21.2	20.2	17.9	15.4	19.5
Control	31.3	34.8	33.4	27.7	31.6	31.8	29.7	33.1	31.8	26.2	30.0	30.2
Mean	22.7	22.0	20.8	17.8	17.4		21.5	20.8	19.7	16.9	16.5	
C.D. at 5%	Spacing: 0.70; Variety: 0.78; Spacing x Variety: 1.56						Spacing: 0.69; Variety: 0.77; Spacing x Variety: 1.55					
60 DAS												
3 × 3	27.2	25.1	21.5	19.4	19.2	22.5	25.8	23.9	20.4	18.4	17.3	21.2
6 × 1.5	34.6	32.5	28.9	25.8	24.8	29.3	32.9	31.0	27.5	24.5	23.5	27.9
17 × 1 × 1	44.3	42.3	37.7	32.7	31.3	37.7	42.1	40.3	35.9	31.1	28.4	35.6
Control	68.0	65.3	54.4	57.7	56.6	60.4	64.7	62.2	51.8	54.9	53.9	57.5
Mean	43.5	41.3	35.6	33.9	33.0		41.4	39.4	33.9	32.2	30.8	
C.D. at 5%	Spacing: 0.71; Variety: 0.79; Spacing x Variety: 1.59						Spacing: 0.82; Variety: 0.91; Spacing x Variety: 1.83					
90 DAS												
3 × 3	54.4	52.9	50.8	48.7	46.5	50.7	51.8	50.3	48.3	46.3	43.3	48.0
6 × 1.5	64.4	62.9	59.6	57.7	55.9	60.1	61.3	59.9	56.7	55.0	52.2	57.0
17 × 1 × 1	73.1	71.5	69.6	67.6	59.2	68.2	69.6	68.1	66.2	64.4	64.0	66.5
Control	92.0	91.1	84.1	85.8	73.0	85.2	87.6	86.8	80.0	81.7	74.9	82.2
Mean	71.0	69.6	66.0	65.0	58.7	-2.0	67.6	66.3	62.8	61.9	58.6	-2.0
C.D. at 5%	Spacing: 2.16; Variety: 2.41; Spacing x Variety: 4.83						Spacing: 2.08; Variety: 2.32; Spacing x Variety: 4.65					
120 DAS												
3 × 3	59.7	58.5	56.9	55.1	53.9	56.8	56.9	55.8	54.1	52.5	50.3	53.9
6 × 1.5	70.8	69.6	66.9	64.1	60.5	66.4	67.4	66.3	63.7	61.1	58.6	63.4
17 × 1 × 1	77.7	76.2	73.2	70.7	67.0	73.0	74.0	72.6	69.7	67.3	65.5	69.8
Control	95.3	93.8	86.8	88.9	88.6	90.7	90.9	89.4	82.6	84.7	84.4	86.4
Mean	75.9	74.5	71.0	69.7	67.5	-2.0	72.3	71.0	67.5	66.4	64.7	-2.0
C.D. at 5%	Spacing: 2.30; Variety: 2.58; Spacing x Variety: 5.16						Spacing: 2.21; Variety: 2.47; Spacing x Variety: 4.95					

Table 2: Dry matter accumulation of wheat varieties during different time intervals of growth under different spacings of eucalyptus

Spacing (m)	2013-14 WH-1105	WH-542	HD-2967	HD-943	DPW-621-50	Mean	2014-15 WH-1105	WH-542	HD-2967	HD-943	DPW-621-50	Mean
30 DAS												
3 × 3	145.6	169.0	251.0	198.7	214.2	195.7	140.1	162.8	241.9	191.3	206.3	188.5
6 × 1.5	171.8	194.1	298.0	222.1	245.0	226.2	165.3	187.0	287.2	213.8	236.1	217.9
17 × 1 × 1	198.7	217.1	346.3	253.2	287.1	260.5	191.3	209.1	333.8	243.7	276.6	250.9
Control	280.2	242.9	366.2	345.2	377.2	322.4	269.7	234.1	353.0	332.3	363.5	310.5
Mean	199.1	205.8	315.4	254.8	280.9		191.6	198.3	304.0	245.3	270.6	
C.D. at 5%	Spacing: 7.88; Variety: 8.81; Spacing x Variety: 17.6						Spacing: 8.10; Variety: 9.06; Spacing x Variety: 18.1					
60 DAS												
3 × 3	409.6	511.9	569.9	464.6	495.0	490.2	394.3	493.2	549.4	447.3	477.0	472.2
6 × 1.5	447.7	587.0	623.1	495.9	544.7	539.7	430.9	565.5	600.6	477.4	524.9	519.9
17 × 1 × 1	494.8	625.8	690.1	536.8	588.7	587.2	476.3	602.9	665.2	516.7	567.2	565.7
Control	823.8	766.6	705.3	598.9	528.1	684.5	793.0	738.7	679.8	576.5	508.8	659.3
Mean	544.0	622.8	647.1	524.1	539.1		523.6	600.1	623.8	504.5	519.5	
C.D. at 5%	Spacing: 17.6; Variety: 19.7; Spacing x Variety: 39.4						Spacing: 17.6; Variety: 19.7; Spacing x Variety: 39.4					
90 DAS												
3 × 3	618.2	792.8	845.6	689.1	747.3	738.6	595.1	763.9	815.1	663.3	720.0	711.5
6 × 1.5	690.1	836.5	917.7	735.2	798.6	795.6	664.3	806.0	884.6	707.6	769.5	766.4
17 × 1 × 1	736.5	900.7	997.9	791.4	830.5	851.4	708.9	867.8	961.9	761.7	800.2	820.1
Control	1067.1	971.0	1013.0	866.9	809.5	945.5	1027.2	935.5	976.5	834.5	779.9	910.7
Mean	778.0	875.3	943.6	770.7	796.5		748.9	843.3	909.5	741.8	767.4	
C.D. at 5%	Spacing: 25.3; Variety: 28.3; Spacing x Variety: 56.7						Spacing: 25.3; Variety: 28.3; Spacing x Variety: 56.7					
120 DAS												
3 × 3	736.6	865.8	941.7	794.5	818.3	831.4	709.0	834.2	907.7	764.7	788.4	800.8

6 × 1.5	794.6	908.9	996.5	823.6	870.9	878.9	764.8	875.8	960.5	792.8	839.1	846.6
17 × 1 × 1	846.6	972.7	1025.2	888.8	915.6	929.8	814.9	937.2	988.3	855.5	882.2	895.6
Control	1213.5	1163.3	1093.4	915.8	890.0	1055.2	1168.1	1120.8	1054.0	881.5	857.5	1016.4
Mean	897.8	977.7	1014.2	855.7	873.7		864.2	942.0	977.6	823.6	841.8	
C.D. at 5%	Spacing: 28.0; Variety: 31.3; Spacing x Variety: 62.7						Spacing: 27.8; Variety: 31.1; Spacing x Variety: 62.2					

Biological yield (t/ha)

The results presented in Fig.1 showed that biological yield differed significantly among wheat varieties both in open field and under various spatial arrangements of eucalyptus trees during both the years. The wheat variety WH-1105 was recorded maximum biological yield closely followed by variety WH-542, HD-2967, HD-943 and DPW-621-50 in control (sole wheat) than different spacings of eucalyptus based agroforestry system during both the years of observations. However, among different spacings of eucalyptus, paired row planting (17 × 1 × 1 m) resulted in significantly higher biological yield in wheat variety HD-2967 (6.30 t/ha) than planting at 6 × 1.5 m (5.80 t/ha) and 3 × 3 m (4.60 t/ha) spacing during 2013-14. The maximum reduction in biological yield was found in variety WH-1105 (86.7%) under 3 × 3 m.

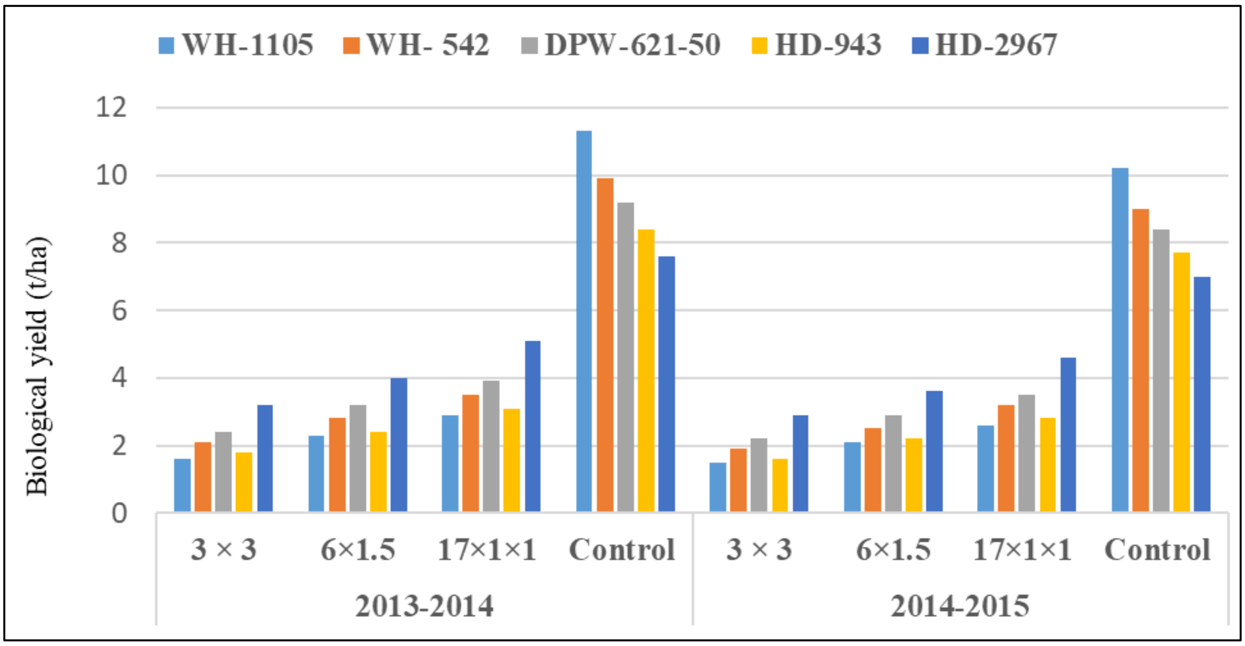

Fig 1: Effect of different eucalyptus spacings on biological yield of various wheat varieties during 2013-14 and 2014-15

Spacing over control and it followed the order: HD-943 (75.0%) > WH 542 (70.7%) > DPW-621-50 (67.2%) > HD-2967 (50.1%) during 2013-14. The reduction in the gross biological yield was due to the reduction in yield contributing factors (plant height, number of grains per spikes and 1000-grain weight), which may have been affected by the micro-environmental changes *i.e.* solar radiation and air temperature under the canopy (Gill *et al.*, 2009) [5]. The reduction in biological yield of wheat under eucalyptus might be attributed to various antagonistic interaction in tree based ecosystem, *i.e.*, reduction in light availability and less availability of CO_2, water and nutrients which created adverse effect on yield attributing factors *i.e.* number of shoots per unit area, plant height and dry matter accumulation. Present results are in conformity with earlier findings of Kumar and Rajput (2005) [8].

Harvest index (%) and Attraction index (%)

It is evident from the data Table 3 that the harvest index and attraction index of different wheat varieties were affected significantly by spacing. The results showed that among different spatial arrangements of eucalyptus, variety HD-2967 exhibited higher harvest index and attraction index (47.7 and 90.9%) which was statistically at par with variety WH-542 (46.5 and 86.7%), DPW-621-50 (45.6 and 83.3%), WH-1105 (45.3 and 82.3%) and HD-943 (45.1 and 81.8%) in paired row planting (18 × 2 × 2 m) of eucalyptus than planting at 10 × 2 m and 5 × 4 m spacing during 2013-14. The lesser harvest index and attraction index was recorded in wheat variety HD-943 (38.2 and 61.8%) as compared to other wheat varieties under 5 × 4 m spacing during 2013-14. However, in control (sole wheat), variety WH-1105 showed maximum harvest index and attraction index (47.9 and 91.5%) which was statistically at par with variety WH-542 (47.6 and 90.4%) and HD-2967 (46.8 and 87.7%) during 2013-14. In all the wheat varieties, the harvest index and attraction index were significantly higher in control as compared to the crop sown under eucalyptus based agroforestry system during both years of observations. Thus this variation in harvest index and attraction index might be due to the variation in grain yield and total biomass production with increase in spacing and age of poplar. Similar results were also reported by Gill *et al.* (2009) [5] in different wheat varieties under poplar.

Table 3: Effect of different eucalyptus spacings on harvest index and attraction index of various wheat varieties during 2013-14 and 2014-15

Harvest index (%)												
	2013-14						**2014-15**					
Spacing (m)	**Wheat varieties**					**Mean**	**Wheat varieties**					**Mean**
	WH-1105	**WH-542**	**HD-2967**	**HD-943**	**DPW-621-50**		**WH-1105**	**WH-542**	**HD-2967**	**HD-943**	**DPW-621-50**	
5 × 4	40.1	41.5	45.8	38.2	40.1	41.1	39.0	40.5	45.2	38.6	40.6	40.8
10 × 2	44.5	45.1	48.4	45.3	44.5	45.6	43.8	44.9	48.1	45.2	44.9	45.4
18 × 2 × 2	45.3	46.5	47.7	45.1	45.6	46.1	45.2	47.0	47.7	44.9	45.0	46.0
Control	47.9	47.6	46.8	46.5	46.2	47.0	47.7	47.6	46.8	46.3	45.9	46.9
Mean	44.5	45.2	47.2	43.8	44.1		43.9	45.0	47.0	43.8	44.1	
C.D. at 5%	Spacing: 1.35; Variety: 1.51; Spacing x Variety: 2.9						Spacing: 0.80; Variety: 0.89; Spacing x Variety: 1.79					
Attraction index (%)												
	2013-14						**2014-15**					
5 × 4	66.7	70.8	84.0	61.8	66.9	70.0	63.9	68.2	82.5	63.1	68.4	69.2
10 × 2	80.2	81.8	93.3	82.3	80.0	83.5	78.2	81.6	92.7	82.7	81.6	83.4
18 × 2 × 2	82.3	86.7	90.9	81.8	83.3	85.0	82.7	88.9	91.0	81.7	81.8	85.2
Control	91.5	90.4	87.7	86.6	85.4	88.3	91.3	90.8	88.0	86.2	84.9	88.3
Mean	80.2	82.4	89.0	78.1	78.9		79.0	82.4	88.6	78.4	79.2	
C.D. at 5%	Spacing: 1.65; Variety: 1.85; Spacing x Variety: 3.71						Spacing: 2.42; Variety: 2.70; Spacing x Variety: 5.41					

Conclusion

Eucalyptus based agroforestry system in Paired row planting (17×1×1 m) was found best for production of wheat followed by 6×1.5 m and 3×3 m. Wheat production data of five wheat varieties grown in association with three spatial arrangements of Eucalypts suggested that HD-2967 variety of wheat was found best as a shade tolerant followed by DPW-621-50 and WH-542.

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