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Impact of planting density on wheat crop grown under different tree species in *tarai* agroforestry system of Central himalaya, India

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Abstract: A field trial based Agroforestry system was established at Pantnagar during *Rabi* season 2012-13 for predicting the effect of spacing on growth and yield of wheat (*Triticum aestivum* L.) under *Eucalyptus camaldulensis* and *Melia azedarach*. The experiment was carried out in split-plot design consisting of two tree species in main plot, viz, *Eucalyptus camaldulensis* and *Melia azedarch* and four spacing treatments in sub-plot *viz*, 3.0m×1.0m, 3.0m×1.5m, 3.0m×2.0m and 3.0m×2.5m with three replications. The wheat crop variety"UP-2338" was sown on December 06, 2012 and harvested on April 27, 2013. Among the tree species, the maximum (15.1 q /ha) and significantly higher grain yield with 21.8% increment was recorded under *Melia as compare to Eucalyptus*. Whereas, among the different spacings, the wheat growth in terms of dry biomass at 120 DAS (495.4/m^2), yield attributes and yield in terms of grain (16.0 q/ha), straw (29.4 q/ha) and biological yield (45.4 q/ha) under *Melia* was significantly higher at 3 × 2.5 m spacing as compared to other planting density. The correlation coefficient (r) studies exhibited that wheat growth and yield attributing characteristics shows significantly ($p<0.05$) high degree ($r=0.75$ to 1) positive correlation with each other. The investigation was done to find out the proper planting density for intercropping of wheat with tree species without comprising the wheat growth and enhancing its sustainability.

Keywords: *Eucalyptus camaldulensis*, Planting density, Tree species, Wheat, Yield

INTRODUCTION

Agroforestry is an important component of the 'evergreen revolution' movement in the country (Puri and Nair, 2004).According to Gibson (1978), agroforestry under high density short rotation plantation has maximum advantages including higher yield per unit area of land and increased labour productivity than conventional forestry. Agroforestry systems not only arrest land degradation but also improve site productivity through interactions among trees, soil, crops, and livestock (Kumar, 2006). This is the most important way to practice agriculture without deteriorating agro-diseases and environmental degradation is highly appreciable (Garrity, 2004).

In North Indian states, wheat (*Triticum aestivum* L.) is the most important and staple food crop when grown under agroforestry system, which holds about 88.31 million tones of production in 2011-12 (Sarvade *et al.* 2014). In India, it is most widely grown cereal crop during *Rabi* season (November-April) which is intercropped with Eucalyptus, Poplar and other short rotation tree species of fast growing nature in Uttarakhand, U.P, Haryana, Punjab, Bihar states in north and parts of central and eastern states of Madhya Pradesh, Chhattisgarh and West Bengal.

The major advantage of agroforestry is that both wood and agricultural products come from the same land base, making it an efficient production system especially in areas where farmers have small holdings. In agroforestry, the micro-climate is modified by different tree species. Under such situations, role of agroforestry in the light of combating hunger, the response of wheat crop under storey might be different from the sole system of cropping. In Indo-Gangetic plains, the technology of wheat production is very well established but may require some refinement in mixed land-use systems technology, like agroforestry, particularly in terms of nutrient management aspect, where wheat crop is grown in association with the trees.

For increasing the food and raw material for industry requirement, intercropping with tree species under high density short rotation is the most appropriate method of natural resources through sustainable utilization of resources (Sarvade *et al*., 2014). *Melia azedarach* is now becoming increasingly common under high density, short-rotation mixed plantations for site amelioration and may have the potential to increase crop yields, maintain soil fertility, also provides fuel wood and fodder.

Hence, the experiment was aimed to ascertain the influence of different tree species and their spacing in

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development and yield of wheat crop.

MATERIALS AND METHODS

The field experiment was conducted at Agroforestry research center, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand (29°N Latitude, 79° 30' E longitude and at an altitude of 243.84 msl) during 2012-2013. The plot comprised silty-clay-loam soil with 1.53 and 1.57% of organic carbon and 253.65 and 365 kg/ha of available nitrogen, 32.32 and 35.84 kg/ha of available phosphorus and 176.55 and 220.4 kg/haof exchangeable potassium in *Eucalyptus* and *Melia*, respectively.

Particulars	Method employed
Soil texture	Silty clay loam
Sand %	10%
Silt %	50%
Clay %	32%
	Derived by Bouyoucas hydrometer method (Bouyoucas,1962)
Organic Carbon (%)	Modified Walkley and Black method (Jackson,1973)
Available Nitrogen (kg ha^{-1})	Alkaline KMnO4 method (Subbiah and Asija, 1956)
Available phosphorus (kg ha^{-1})	Olsen's method (Jackson,1973)
Available potassium (kg ha^{-1})	Flame emission spectrophotometer (Jackson,1973**)**

Important physio-chemical properties of experimental soil

The site is characterized by a humid sub-tropical, cold and hot dry summers with 1350 mm mean annual rainfall, of which 80 to 90% is received between June and September. The remaining 10 to 20% rainfall is received during wheat-growing season (November to April of year 2012-13).The weather data was collected from the agrometeorological observatory located at the Norman E. Borlaug Crop Research Centre, G. B. Pant University of Agriculture and Technology, Pantnagar. Intercropping of wheat crop was done under short rotation fast growing tree species. Two tree species of T1: *Eucalyptus*, K23 (*Eucalyptus camaldulensis*) and T2: *Melia*, Local (*Melia azedarach*) were planted in 2007 with four spacing treatments of S1: 3m × 1.0 m, S2: 3m × 1.5 m, S3: 3m × 2 m and S4: 3m × 2.5 m. The wheat (UP-2338)was sown with a uniform row-to-row distance of 17.5 cm using seed rate 100 kg /ha. The crop was fertilized with 120 kg N, 60 kg P_2O_5 and 40 kg K_2O per hectare through urea, single super phosphate and murate of potash, respectively. Half dose of nitrogen (60 kg/ha) and full dose of phosphorus (60 kg/ha) and potash (40 kg/ha) were applied as basal dressing and mixed thoroughly with the help of spade manually before crop sowing. Remaining dose of nitrogen was top dressed a day before first irrigation at Crown Root Initiation CRI stage. Wheat crop was irrigated thrice (at crown root initiation, late jointing and milk stages of the crop growth). However, no separate irrigation was provided for tree component. For the control of weeds, a broad spectrum herbicide (Sulfosulfuron @ 25g a.i. /ha) was sprayed at 35th days after sowing (DAS). The experiment was designed as split-split-plot with two species in main plots, spacing in sub-plots and treatments were replicated thrice.

The dry matter accumulation was recorded at maturity stage (120 DAS). The different yield attributing characters like spike length (cm), fertile spikelet/ spike, sterile spikelet/spike, grain number/spike and 1000-grain weight were evaluated at time of physiological maturity. The net plots were harvested to obtain grain/ seed, straw and biological yield. Harvest index was calculated as the ratio of grain to total biological yield. Data obtained during the course of this investigation, was analyzed by using standard statistical procedure for split plot design with the help of computer for analysis of variance (ANOVA) technique (Snedecor and Cochran, 1967). Standard error of mean (SEm±) were computed in each case. The differences among treatments were compared by applying "F" test of significance at 5% probability. Correlation studies (Panse and Sukhatme, 1978) were also performed to study the inter-relationship between various parameters.

RESULTS AND DISCUSSION

Wheat growth: Dry matter accumulation in wheat crop (g/m^2) at 120 DAS was significantly influenced by tree species and their spacing (Table 1). Dry matter accumulation was significantly higher in *Melia* (526.3 g/m^2) as compared to *Eucalyptus* (428.5 g/m^2) which shows about 22.8 % increase in biomass accumulation. Whereas, among the different spacing, significantly higher dry matter of wheat was recorded at maximum spacing of 3.0m x 2.5m. Reduction under *Eucalyptus* may be attributed to its allelopathic effect on understory crops and more canopy density resulting in greater shade. Similar findings were recorded by Fikreyesus *et al.* (2011) in the case of tomato; Ahmed *et al.* (2008); Kaushik and Singh (2001) for agricultural *Rabi* crops. The wheat produced highest total plant dry matter with widest spacing (3.0m x 2.5m) under both the tree species and consistent reduction was observed with each decrease in tree spacing. Sarvade *et al.* (2014) reported 10.3% reduction of dry matter accumulation (g/m^2) with decrease in plant spacing from3.0m x 2.5mto 3.0m x 1.0m.The reduction in dry matter accumulation (g/m^2) with increased tree density has primarily been attributed due to increased shading effects and competition for nutrients, space and water. Being an evergreen tree species, *Eucalyptus* reduces light availability and decreased crop yield. Corroborative results were reported by Kaushik and Singh (2001), Kumar

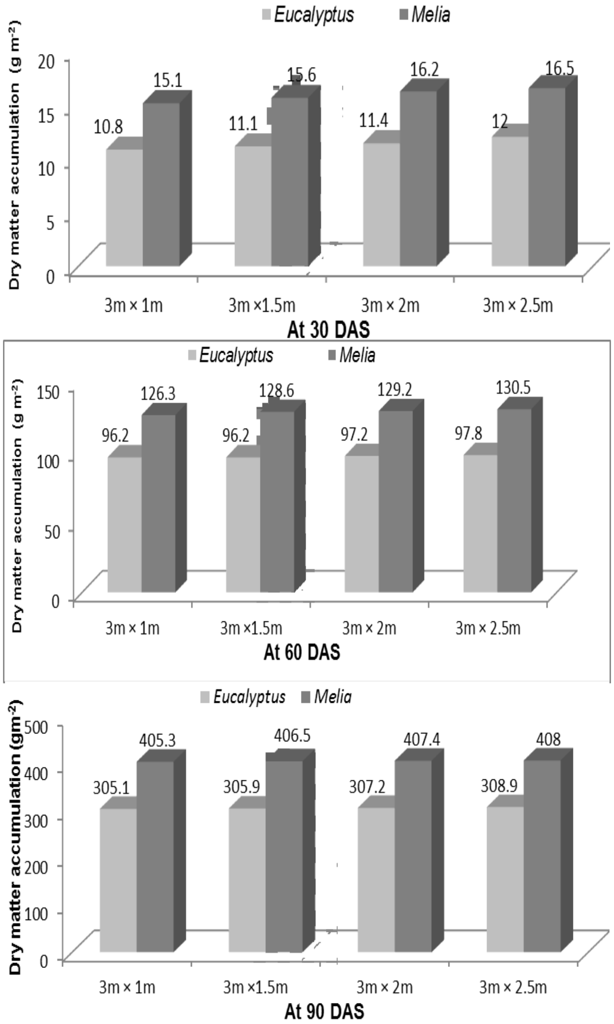

Fig. 1. *Effect of tree species and spacing on dry matter accumulation of wheat crop at various stages.*

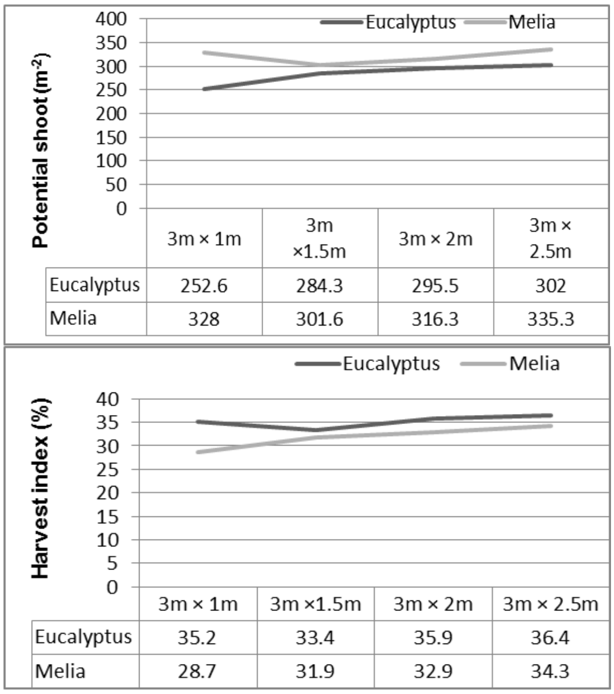

Fig. 2. *Interaction among tree species and different spacing.*

and Rajput (2003), Tripathi *et al*. (2006), Ahmed *et al.* (2008) and Fikreyesus *et al.* (2011).

Yield attributes: The different yield attributing characters viz, average spike length (cm), fertile spikelet/spike, sterile spikelet/spike, grain number/spike and 1000-grain weight (test weight) didn't show any significant differences due to tree species.

The higher (320.3/m^2) and significantly more number of potential shoots were recorded under *Melia* than *Eucalyptus* which recorded (283.5/m^2) with 13.0% of increment. Spacing also significantly influenced potential shoot and increased with decrease in tree density. Potential shoot (318.6/m^2) at 3.0m x 2.5m spacing was significantly higher than 3.0m x 1.0m and 3.0m x 1.5m spacing but was at par with 3.0m x 2.0m spacing.

Spike length was significantly influenced by spacing and increase with decreased in tree density. *Melia* recorded 13.1% increment over *Eucalyptus*. It was found to be higher (9.65 cm) at 3.0m x 2.5m spacing and was at par with its respective lower dose at 3.0m x 2.0m

Table1. Effect of different tree species and spacing on wheat growth and yield attributes.

Treatments	Germination count (per m^2)	Dry matter accumulation (per m^2) at 120 DAS	Potential shoot (per m^2)	Spike length (cm)	Fertile spikelet/spike	Sterile spikelet/spike	Grain /spike	1000 grain weight(g)
Sole crop	**274.3**	**1051.6**	**400.3**	**10.6**	**17.3**	**3.0**	**45.6**	**43.4**
A. Tree species								
Eucalyptus	205.0	428.5	283.5	8.41	15.11	1.60	30.2	25.69
Melia	217.6	526.3	320.3	9.51	16.21	2.25	35.7	30.36
SEd±	2.54	2.70	3.50	0.36	0.37	0.55	2.67	1.65
CD (P=0.05)	10.63	11.32	14.66	NS	NS	NS	NS	NS
B. Tree spacing								
3m × 1m	200.5	464.3	290.3	5.48	15.5	1.83	29.16	26.65
3m × 1.5m	208.3	473.0	293.0	8.30	15.0	1.50	32.0	26.25
3m × 2m	214.1	477.0	305.8	9.13	15.8	2.16	34.33	28.59
3m × 2.5m	222.3	495.4	318.6	9.65	16.3	2.21	36.50	30.63
SEd±	5.47	3.96	7.38	0.29	0.29	0.29	1.56	0.70
CD (P=0.05)	11.93	8.63	16.08	0.64	0.64	NS	3.41	1.54
Interaction(A×B)	NS	NS	S	NS	NS	NS	NS	NS

Table 2. Yield of wheat crop under tree species and their spacing under high density plantation.

Treatments	Yield attributes (q /ha)			
	Grain yield	Straw yield	Biological yield	Harvest index (%)
Sole crop	**27.9**	**51.8**	**79.7**	**35.5**
A.Tree species				
Eucalyptus	12.4	22.7	35.1	35.3
Melia	15.1	31.9	47.1	32.0
SEd±	0.33	0.39	0.07	0.99
CD (P=0.05)	1.42	1.63	0.29	NS
B.Tree spacing				
3m × 1m	11.5	25.1	36.6	32.0
3m × 1.5m	13.0	26.9	39.9	32.7
3m × 2m	14.5	27.9	42.5	34.4
3m × 2.5m	16.0	29.4	45.4	35.4
SEd±	0.41	0.33	0.50	0.79
CD (P=0.05)	0.90	0.72	1.10	1.72
Interaction(A×B)	NS	NS	NS	S

spacing and significantly superior to rest of the spacings. Similar results were recorded with fertile spikelets/spike with 7.3% as comparison to *Eucalyptus*. Maximum fertile spikelets/spike (16.3) was obtained under 3.0m x 2.5m spacing and decreased with decrease in density of tree species except with 3.0m x 1.5m spacing.

The highest (36.50) grains/spike have been recorded under 3.0m x 2.5m spacing. The number of grains/ spike at 3.0m x 2.5m spacing was significantly higher than 3.0m x 1.0m and 3.0m x 1.5m spacing and was at par under 3.0m x 1.5m spacing. Test weight at 3.0m x 2.5m spacing (30.63 g) was significantly higher than all other spacing. However, the difference between the thousand grains weight with 3.0m x 1.0m and 3.0m x 1.5m spacing was found to be non-significant. *Melia* shows 18.2% of increment in grains/spike than *Eucalyptus*. The yield attributes are mainly depends on the crop growth and significantly affected by tree species and as they affect wheat growth. Similar findings have been reported by various scientists (Jiang *et al*., 1994; Khan and Ehrenreich, 1994; Lakshmamma and Subba Rao, 1996; Tripathi *et al*., 2006). Puri *et al.* (2001) also found the number of effective tillers and seeds per spike in wheat to be influenced significantly in agri-silvicultural system with significant varietal differences. It is visualized that higher potential shoots and more number of grains/spikehave basically been responsible for higher grain yield in wheat. Number of grains/spike has been shown to be reduced by shading during ear growth (Fischer and Stockman, 1980; Stockman *et al.,*1983; Fischer, 1985).Puri *et al*. (2001) also found the number of effective tillers and seeds per spike in wheat to be influenced significantly in agri-silvicultural system with significant varietal differences. The significant reduction in test weight and pods/plant of lentil and mungbean under varying spacing of *Dalbergia sissoo* compared to open have also been reported by Nandal and Singh (2001). The present study shows that *Eucalyptus* being an evergreen species affects the yield and yield attributing characters of wheat due to its shading effect. Similarly, Nazir *et al.* (1993) also observed that 1000-grain weight of wheat decreased significantly under *Dalbergia sissoo* with increased duration of shading. Similar findings have been reported by Tripathi *et al.*, 2006.

Yield: Crop yield was influenced differently by different tree species and spacing. The maximum total biological, grain, straw wheat yields were obtained under control (sole crop) which was substantially high than *Melia and Eucalyptus* (Table 2). All the yield attributing characters viz., grain, straw and biological yield were achieved maximum (15.1, 31.9 and 47.1 q /ha), respectively, when intercropped with *Melia* and was significantly superior to wheat intercropped with *Eucalyptus* with increase percent of 21.8, 40.5 and 34.2%, respectively. Among the different spacing, 3m × 2.5mspacing was proved to be more effective and significantly superior in obtaining maximum yield than its respective other spacing. However, interaction among the different tree species and spacing was found to be non significant. The yields (biological, grain and straw) were observed and the per cent reduction was recorded higher under *Eucalyptus* (55.55, 56.20 and 55.97%, respectively) than *Melia* (45.87, 38.45 and 40.91%, respectively) in comparison to sole crop condition. Number of studies has shown reduced grain, straw and/or biological yields under trees (Kaushik and Singh, 2001; Puri *et al*., 2001; Kaushik *et al*., 2001 and Verma *et al*., 2002). Mu *et al.* (2010) reported that the wheat grain yield losses were proportionately less than the reduction in solar radiation under shading by trees in agroforestry and also corroborative findings have been reported by various scientists (Sidhu and Hans, 1988; Chauhan *et al.*, 1995; Patil *et al*., 2002 and Kidanu *et al*., 2005)

Harvest index was recorded highest (35.4%) with wider spacing at 3m × 2.5m which was at par with its respective narrow spacing at 3m × 2.0m but was at par with other two spacing (3m × 1.0m and 3m × 1.5m). Interaction among the tree species and spacing was significant.

Table 3. Gross income and economic gain (`/ha) over sole crop from agri-silvicultural system with different tree species and their spacings.

Treatment	Income from wheat crop(`/ha)	Income from Trees		Total income from system	
	(Grain +straw)	Timber quantity (Tonnes/ha)	Income (`/ha)	(Timber+ wheat) (`/ ha)	Gain over sole crop (`/ha)
Sole crop	**44,198**			**44,198**	
Tree species					
Eucalyptus	19,240	10.36	43,056	62,296	18,098
Melia	23,904	6.19	24,763	48,667	4,469
Tree spacing					
3.0m x1.0m	21,062	9.08	40,860	61,922	17,724
3.0m x1.5m	21,697	8.05	36,234	57,931	13,733
3.0m x2.0m	22,805	7.56	34,034	56,839	12,641
3.0m x2.5m	23,926	5.88	26,460	50,386	6,188

Note: Total value was calculated according to current market price; `1120/qt for wheat, `250/qt for straw, `600/qt for *Eucalyptus* and *Melia* wood and `400/qt. For spacings- the average of timber prices of all the species was taken to calculate income.

Table 4. Correlation growth, yields attributes and yields of wheat under agroforestry system.

Characters	2	3	4	5	6	7	8	9	10	11
1	.975**	.990**	.707	.896**	.903**	.975**	.991**	1.000**	.983**	.993**
2		.971**	.556	.840*	.858*	.913**	.976**	.978**	.985**	.986**
3			.676	.936**	.940**	.978**	.998**	.990**	.993**	.996**
4				.657	.652	.804*	.654	.697	.636	.662
5					.988**	.932**	.934**	.894**	.896**	.899**
6						.932**	.939**	.904**	.907**	.910**
7							.969**	.972**	.959**	.967**
8								.992**	.990**	.994**
9									.984**	.994**
10										.998**

** Significant at 1% level of probability; * Significant at 5% level of probability, Germination count; 2- dry matter accumulation at 120 DAS; 3- Potential shoot; 4- Spike length; 5- Fertile spike per spikelet; 6- Sterile spike per spikelet; 7- grains per spike; 8- 100 grain weight; 9- grain yield; 10- straw yield; 11- biological yield.

Economics of the system: Economic benefits from different tree species and their spacings in agrisilvicultural system with wheat as intercrop during this particular crop season are given in Table 4.7. For the calculation of timber quantity, the specific gravity (Pande, 2011), 0.60 and 0.66 has been taken for Eucalyptus and *Melia* species, respectively, whereas, for spacing, the average specific gravity of both timber species was taken.

Gross income for the system (`/ha) was worked out to be `62296 and 48667/-for *Eucalyptus* and *Melia,* respectively, and `61922, 57931, 56839 and 50386/- for tree spacing s*viz.*3.0m x 1.0m, 3.0 m x 1.5m, 3.0 m x 2.0m and 3.0m x 2.5m, respectively. Whereas, sole crop gave a net return of only`44198/-from wheat. The gain of `18098 and 4469/ha over sole crop was obtained with *Eucalyptus* and *Melia* based system, respectively.

Among spacing, the net gain of `17724, 13733, 12641 and 6188/ha over sole crop was realized with 3.0m x 1.0m, 3.0m x 1.5m, 3.0m x 2.0m and 3.0m x 2.5m, respectively.

Apart from additional income over sole crop or traditional agri-system, fuel wood from pruning, soil fertility improvement and timber were major driving force for adoption for *Eucalyptus* and *Melia* wood. For spacings-the average of timber prices of all the species was taken to calculate income of agroforestry. *Eucalyptus* based commercial agroforestry systems are comparatively more profitable than *Melia* in agroforestry systems and the conventional cropping patterns. The contribution of the trees in the farming systems certainly added to the diversity dimension by way of income and employment to the farm households besides fulfilling the requirement of wood (Dwivedi *et al.,* 2007).

Correlation study: Correlations between growth, yield attributing characters and grain yield under two tree species were evaluated for the present study (Table 4). The grain yield shows high degree of positive correlation with all the yield attributes except spike length. However, germination count was perfectly (r=1) positive correlated with grain yield.

Germination count, dry matter accumulation and potential shoot had significant positive high degree of correlation (r=0.75 to 1) with all other growth parameters and yield except spike length. Spike length was significantly highly positive correlated only with grain per spike with significancy of r=0.804. Fertile spikelet/ spike, sterile spikelet/spike, grains/spike, 100 grain weight, grain, straw and biological yield showed significant high degree of positive correlation with each other. Similar data or result on these lines was also reported by Subhani and Chowdhry (2000) and Attarbashi *et al*. (2002). Sarvade *et al*., (2014) also found the similar results on correlation among the different wheat growth parameters.

The higher degree of correlation shows that the higher yield dependency of yield attributes on the crop growth and thus influences its yield. As the spike length did not show any significancy with other parameters and were positive and non-significantly correlated to each other ($r<0.75^{NS}$), showing that as spike length increases the grains per spike will increase ultimately. The results from correlation of germination count indicated that significantly positive association with yield attributing characters like dry matter accumulation, potential shoot, spikelet per spike^{-1}, grain per spike, grain yield etc. except spike length revealed that increase in germination count will cause corresponding increase in associated traits. Germination count (no./m^2) was perfectly positively associated and coefficient determination (r=1) with grain yield (q/ha), hence this yield component can be used as reliable selection criteria to improve grain yield in wheat.

Conclusion

From the present study, it may be concluded that *Melia azedarach* was found better for intercropping of wheat as it reduces competition for light with crop by shedding their leaves during crop sowing period which may helps to improve soil properties. Whereas, among the different tree spacing, wider spacing of 3m × 2.5m was recorded superior in improving the growth, yield attributes and yields of wheat. However, economically wheat under *Eucalyptus* gain more income because of timber addition as of higher biomass accumulation in bole. Estimation of correlation among yield and yield components may provide effective selection criteria to improve wheat grain yield.

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