Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(1): 1161-1167
Received: 08-11-2017
Accepted: 09-12-2017

Akanksha Bisht
Department of Agronomy, G.B. Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand, India

SK Lavania
Department of Agronomy, G.B. Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand, India

Praveen Kumar Singh
Department of Vegetable Science, Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad, Uttar Pradesh, India

Yamuna Prasad Singh
Department of Vegetable Science, Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad, Uttar Pradesh, India

Correspondence
Akanksha Bisht
Department of Agronomy, G.B. Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand, India

Study the comparative yield and yield attributes of wheat (*Triticum aestivum* L.) Under open and *Populus* based agroforestry system

Akanksha Bisht, SK Lavania, Praveen Kumar Singh and Yamuna Prasad Singh

Abstract

The field experiment was carried out in Agroforestry Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand during the *rabi* season for two years 2014-15 and 2015-16 to study the comparative performance of wheat varieties under poplar based agroforestry system. Five wheat (*Triticum aestivum* L.) varieties (PBW-343, UP-2565, WH-711, DBW-17 and VL-907) were tested in randomized block design with three replications (under poplar plantation and in open field) during both the years. Among different wheat varieties under poplar based agroforestry system, spike length was found significantly higher in UP-2565, number of fertile spikelets, grains per spike, grain weight per spike and test weight in VL-907 under poplar based agroforestry system while number of infertile spikelets was observed higher in PBW-343 during both the years. Wheat variety VL-907 showed the maximum biological yield among wheat varieties under poplar based agroforestry system during Y_1 and Y_2.while, biological yield was lower among different wheat varieties under poplar based agroforestry system than open farming system. Maximum grain yield under poplar based agroforestry system was recorded in wheat variety VL-907 during Y_1 and Y_2, respectively, However open farming system had more grain yield than poplar based agroforestry system. Straw yield was also more in VL-907 in 2014-15 and in 2015-16 more in PBW-343 under poplar based agroforestry system. Among wheat varieties, VL-907 had maximum harvest index in poplar based agroforestry system. Harvest index was higher in poplar based agroforestry system than open farming system. Among the different wheat varieties grown with poplar, wheat variety VL-907 gave the better performance under agroforestry system as well as open farming system during both the years of experiments.

Keywords: Wheat, inter-cropping, growth, yield, agro-forestry system

Introduction

The rising population pressure and urbanization, coupled with land degradation and global warming are the major causes for un-sustainability in food production in developing world. Among different approaches to combat this problem, agroforestry or woody perennial based intercropping system, has proved itself as a key component of sustainable agriculture and is popular in addressing the issues related to supply of wood, fuel and fodder to preserve fragile agro-ecosystem. It not only arrest land degradation but also improves site productivity through interaction among trees, soil, crops and/or livestock, and thus restore part, if not all of the degraded lands (Kumar, 2006) [10]. Wheat (*Triticum aestivum* L.) is widely intercropped cereal crop during *rabi* season (November-April) with Poplar, Eucalyptus and other fast growing tree species in northern states of India viz., Uttarakhand, Punjab, Haryana, Uttar Pradesh and Bihar, parts of central and eastern states such as Madhya Pradesh, Chhattisgarh and West Bengal. Poplar and Eucalyptus are the most successful industrial agroforestry tree species in India with extremely high productivity upto 10-30 m^3 ha-1yr-1. Competition for resources (above and below ground) may limit productivity of wheat crop after 3 to 4 year of plantation. Wheat yield reduction was recorded 9.4%, 9.9% and 23.3% under one year, two year and three year old poplar plantation, respectively (Ralhan *et al*., 1992) [16]. Agroforestry systems help to reduce the use of chemical fertilizer reduce surface run off, nutrient leaching and can maintain the nutrient requirement for the plant by nutrient recycling (Nair, 1984; Auclair and Dupraz

1999; Gliessmann, 2007) [14, 2, 8]. Agroforestry settings with intercropped is such a cropping system to utilize time, space, labor and natural resources efficiently and sustainably (Sommariba *et al*., 1998; Scholl and Nieuwenhuis, 2004) [22, 19]. In an agroforestry system with poplar and wheat in tropical countries, solar radiation and air temperature was decreased and relative humidity was increased close to the trees. Growth and development of wheat were enhanced by these changes in the microclimate (Fang *et al.*, 2005) [7].

In Northern India, exotic species of *Populus* viz., *Populus deltoides* is being grown enormously as an agroforestry tree by farmers on field bunds, within agricultural fields as block plantation, wastelands etc. It is widely grown in Punjab, Haryana, Himachal Pradesh, Jammu & Kashmir, U.P, Uttarakhand and Arunachal Pradesh. It grows well in deep, fertile, well drained loamy soil. Clones having compact and sparse crown, moderate spread and deep rooting habit are however, less competitive with wheat and other relative crops. Shade tolerance of the variety included is yet another determinant of productivity of wheat under poplar (Singh and Pathak 1993) [21]. Tolerant varieties are appropriate to continue high productivity under increasing levels of canopy closure with age. In the context of global climate change and sustainable development, agroforestry management activities play a vital role through mitigation. However, agroforestry ecosystems are likewise influenced by climate change, thus to mitigation strategies, may be affected by stresses (e.g. heat waves, drought, diseases and natural disturbances) whose rise in frequency and intensity is regarded very likely in a climate change scenario. Being deciduous nature of *Populus deltoides* cultivation of crops during winter season is preferred and majority of the farmers of tarai region grow wheat in poplar based agroforestry system. Tolerance of different wheat varieties under poplar based agroforestry system is required to be screened for their performance. Under agroforestry, the environment is somewhat modified because of the presence of trees, and hence the growth response of understory wheat crop may be different from sole cropping system. New wheat varieties needs to be constantly evaluated under agroforestry for their performance as understory crop. In order to obtain maximum yield from wheat, especially under the tarai region of northern India, the soil environment must be well aerated or a genotype which can withstand temporary oxygen stress is a prime demand to be a successful crop for which suitable varieties and production practices need to be developed. In the present study, the widely grown wheat varieties among the farmers were selected for investigation. In the altering climatic conditions, varietal assessment has been taken up for their suitability under tree canopy. The ultimate aim of the present study is to investigate how the interactions between intercropped wheat varieties are influenced by poplar trees in an agroforestry system. The overall aim of this study is to investigate how the interactions between intercropped wheat varieties are influenced by poplar trees in an agroforestry system. Poplar *(Populus deltoides* Bartr. ex Marsh.), a native to North America has proven outstanding efficiency as an exotic industrial timber species in northern India since the mid 1980s. This tree species is raised on field boundaries or in compact blocks along with agricultural crops like wheat, sugarcane, turmeric, mentha, vegetables, etc. Its popularity with the farmers is primarily because of its fast growth rate, multiutility of the wood, high market prices, less competition with associated crops and pruning-tolerant habit. Poplar belongs to the family Salicaceae, mostly found in tropical region between 28°-36° N latitude and 70°-100° N longitude. Growth of poplar relies upon different factors for example clone, quality of planting stock, site quality, trees spacing, intercrops, climate and management practices.

It is widely grown in Punjab, Haryana, Himachal Pradesh, Jammu & Kashmir, U.P, and Uttarakhand. It develops well in deep, fertile, well drained loamy soil with sufficient moisture.

Materials and Methods

The field experiment was carried out in Agroforestry Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand during the *rabi* season for two years 2014-15 and 2015-16 to Study the comparative yield and yield attributes of wheat under open and *Populus* based agroforestry system with five treatments (wheat varieties) i.e.; T1: PBW -343 (Timely Sown, Irrigated), T2: UP -2565 (Timely Sown, Irrigated), T3: WH - 711 (Timely Sown, Irrigated), T4: DBW -17 (Timely Sown, Irrigated) and T5: VL -907 (Timely Sown, Irrigated) were tested in randomized block design with three replications (under poplar plantation and in open field) with spacing 7m × 3m, date of wheat sowing 22. 11. 2014 (Y_1) and 21.11.2015 (Y_2) whereas, poplar planting was done in 2012. Mechanically, in the open furrows at a row to row distance of 23cm @ 100kg seed per hectare seeds of wheat varieties were sown. As per the soil test value mixture 120 kg nitrogen, 80 kg phosphorus and 40 kg potassium per hectare were applied through urea, single super phosphate and murate of potash, respectively. At the time of sowing the half dose of nitrogen (N) and 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 and all recommended cultural practices done. Crop was harvested when the grain became hard and seed contain 19-20% moisture. Harvesting was done manually by sickle. Morning is the best time for harvesting because at that time shattering loss will be less. Harvested crop was allowed to sun drying for 3-4 days and threshed to separate grain and straw. Observation were recorded on yield and yield attributes traits of wheat under open and *Populus* based agroforestry system i.e.; Spike length (cm), Number of spikelets per spike, Number of fertile & infertile spikelets, Total number of grains per spike, 1000 grain weight, Biological yield (kg ha^{-1}), Grain yield (kg ha^{-1}), Straw yield (kg ha^{-1}) and Harvest index (Wnuk *et al.*, 2013) [25].

Results and Discussion

During 2014-15 and 2015-16, germination count (per m row length) of different wheat varieties ranged from 40.9-43.8 and 36.9-39.4, respectively under poplar. However, the difference among different wheat varieties was non-significant during both the years. Highest germination count was observed in VL-907 (43.8 and 39.4) and lowest in DBW-17 (40.9 and 36.9) during 2014-15 and 2015-16, respectively. The reduction per cent as compared to open (without poplar) increased with age i.e., higher reduction was observed in 2015-16 (4th year) than 2014-15 (3rd year). In 2014-15, maximum reduction was recorded in DBW-17 (3.53%) and minimum in VL-907 (2.23%) however, in 2015-16 maximum reduction was in VL-907 (9.83%) and minimum in DBW-17

(6.58%). The results of both the years revealed that there was slight decrease in germination of different varieties under poplar tree compared to open. The decrease in germination count under poplar may be due to shading effect and litter fall of poplar coinciding with wheat germination. Similarly, different workers also reported reduced germination due to presence of various growth inhibiting substances like tannin, wax, phenolics in the leaf leachates of the poplar reduced the germination count of wheat (Joshi and Prakash, 1992; Kundu, 1994; Nandal and Dhillon, 2007 and Singh *et al.*, 2012) [9, 12, 15, 20]. Spike length was found significantly higher in UP-2565, number of fertile spikelets, grains per spike, grain weight per spike and test weight in VL-907 under poplar based agroforestry system while number of infertile spikelets was observed higher in PBW-343 under poplar based agroforestry system during both the years (Mishra *et al*., 2010 and Tripathi *et al.*, 2006) [13, 24]. Wheat variety VL-907 showed the maximum biological yield among wheat varieties under poplar based agroforestry system during Y_1 and Y_2 same results suggested by Alka *et al.* (2006) [1] and Chauhan *et al.* (2015a). Biological yield was lower among different wheat varieties under poplar based agroforestry system than open farming system. Maximum grain yield under poplar based agroforestry system was recorded in wheat variety VL-907 (193.00 kg ha^{-1}) and (197.00 kg ha^{-1}) during 2014-15 and 2015-16, respectively (Chauhan *et al.*, 2011 and Bisht *et al.*, 2016) [4, 3]. However open farming system had more grain yield than poplar based agroforestry system. Straw yield was more in VL-907 in 2014-15 and in 2015-16 more in PBW-343 under poplar based agroforestry system. Among wheat varieties, VL-907 had maximum harvest index in poplar based agroforestry system same findings by Kumar (2015) [11]. Harvest index was higher in poplar based agroforestry system than open farming system. The maximum dry matter accumulation (19.6 g m^{-2}) in VL-907 and minimum (13.1 g m^{-2}) in DBW-17 in poplar based agroforestry system 2014-15 at 30 DAS. In 2014-15 at 60 DAS, DBW-17 showed the maximum reduction, which was 6.65% and VL-907 showed the minimum reduction per cent of 3.09%. Plant dry matter accumulation ranged from 145.3 to 179.6 g m^{-2} under poplar based agroforestry system. During 90 DAS in 2014-15 maximum dry matter accumulation (420.66 g m^{-2}) was observed in VL-907 and minimum (360.26 m^{-2}) in DBW-17 under poplar based agroforestry system. The maximum dry matter accumulation of 951.3 g m^{-2} was observed in VL-907 and minimum 790.33 g m^{-2} in DBW-17 in 2014-15 during harvesting. The maximum dry matter accumulation (18g m^{-2}) in VL-907 and minimum (12.33g m^{-2}) in DBW-17 in poplar based agroforestry system during both the years 2015-16 at 30 DAS. In 2015-16 at 60 DAS, maximum plant dry matter accumulation was again observed in VL-907 which was 165.06 g m^{-2} and minimum in DBW-17 (149.06 g m^{-2}) under poplar based agroforestry system. Plant dry matter accumulation varied from 149.06. Maximum dry matter accumulation (402.66 g m^{-2}) was observed in VL-907 and minimum (344.33 g m^{-2}) in DBW-17 under poplar based agroforestry system at 90 DAS in 2015-16. The maximum dry matter accumulation was found in 905.0 g m^{-2} in VL-907 and minimum 737.1g m^{-2} in DBW-17 in 2015-16 during harvesting. During both the years, it was observed that the dry matter accumulation was significantly affected by the poplar tree except at 90 DAS. This may be due to the allelopathic effect of poplar tree on wheat plant, competition for light, water and nutrients below the ground level. Reduction in dry matter accumulation under trees was also reported (Rao and Reddy, 1984; Tomar *et al.*, 1997; Das and Chaturvedi, 2005; Eskandari and Ghanbari, 2010 and Sarvade *et al.*, 2014) [17, 23, 5, 6, 18].

During the year 2014-15 and 2015-16 the different wheat varieties under poplar based agroforestry system showed that all the varieties are high yielding but the comparison among different wheat varieties studied that the performance of wheat variety VL-907 in grains per spike, grains weight per spike, test weight, number of fertile spikelets, biological yield, grain yield, straw yield, harvest index, The order of the performance of wheat varieties are as follows: VL-907 > PBW-343 > UP-2565 > WH-711 > DBW-17.

It is concluded that yield and yield attributes of different wheat varieties under open farming system and poplar based agroforestry system are as follows: VL-907 > PBW-343 > UP-2565 > WH-711 > DBW-17, which is the best for farmers in inter cropping system and it also may be recommended for commercial cultivation.

Table 1: Germination count of different wheat varieties under poplar based agroforestry system.

Treatments	Germination count (per m row length)			
	2014-15	**% Reduction**	**2015-16**	**% Reduction**
PBW- 343	42.7 (44.1)*	3.17	39.0 (42.7)*	8.66
UP-2565	42.3 (43.7)	3.20	38.7 (41.8)	7.41
WH- 711	41.7 (43.1)	3.24	37.6 (40.6)	7.38
DBW-17	40.9 (42.4)	3.53	36.9 (39.5)	6.58
VL-907	43.8 (44.8)	2.23	39.4 (43.7)	9.83
SEm±	0.88		0.65	
CD at 5%	NS		NS	
CV	3.63		2.87	

*Figures in parentheses are respective values for control (open), R= Reduction

Table 2: Spike length and grains per spike of different wheat varieties under poplar based agroforestry system.

Treatments	Spike length (cm)				Grains per spike			
	2014-15	% R	2015-16	% R	2014-15	% R	2015-16	% R
PBW-343	10.73 (10.93)*	1.82	10.93 (11.03)*	0.90	43.96 (46.46)*	5.38	44.36 (46.16)*	3.89
UP-2565	11.36 (11.53)	1.47	11.26 (11.36)	0.88	42.96 (46.83)	8.26	41.36 (44.13)	6.27
WH-711	10.13 (10.33)	1.93	10.33 (10.53)	1.89	38.16 (40.83)	6.53	36.76 (39.63)	7.24
DBW-17	10.53 (10.63)	0.94	10.50 (10.73)	2.14	36.23 (39.0)	7.10	36.10 (38.63)	6.54
VL-907	11.00 (11.16)	1.43	11.16 (11.2)	0.35	45.30 (48.13)	5.87	44.86 (46.63)	3.79
SEm±	0.083		0.095		1.12		1.07	
CD at 5%	0.27		0.31		3.56		3.48	
CV	0.39		1.54		4.69		4.55	

*Figures in parentheses are respective values for control (open), R= Reduction

Table 3: Grains weight per spike and test weight of different wheat varieties under poplar based agroforestry system.

Treatments	Grains weight per spike (g)				Test weight (g)			
	2014-15	% R	2015-16	% R	2014-15	% R	2015-16	% R
PBW-343	1.85 (1.93)*	4.14	1.88 (1.97)*	4.56	48.13 (52.2)*	7.79	47.80 (48.06)*	0.54
UP-2565	1.79 (1.88)	4.78	1.72 (1.85)	7.02	46.46 (49.2)	5.56	47.33 (49.36)	4.11
WH-711	1.74 (1.77)	1.69	1.66 (1.78)	6.74	43.06 (47.43)	9.21	44.83 (47.73)	6.07
DBW-17	1.60 (1.72)	6.69	1.64 (1.77)	7.34	41.56 (44.06)	5.67	42.83 (44.9)	4.61
VL-907	1.93 (2.09)	7.65	1.97 (2.05)	3.90	50.06 (53.83)	7.0	49.90 (51.5)	3.10
SEm±	0.054		0.053		0.81		0.860	
CD at 5%	0.17		0.17		2.65		2.80	
CV	5.32		5.20		3.07		3.20	

*Figures in parentheses are respective values for control (open), R= Reduction

Table 4: Fertile spikelets and infertile spikelets of different wheat varieties under poplar based agroforestry system.

Treatments	Fertile spikelets				Infertile spikelets			
	2014-15	% R	2015-16	% R	2014-15	% I	2015-16	% I
PBW-343	18.16 (18.66)*	2.67	17.56 (18.06)*	2.76	4.43 (4.2)*	5.47	4.30 (4.23)*	1.65
UP-2565	17.50 (18.1)	3.31	17.30 (17.63)	1.87	4.33 (4.00)	8.25	4.16 (3.96)	5.05
WH-711	16.83 (17.23)	2.32	16.80 (17.13)	1.92	4.16 (3.8)	9.47	4.03 (3.93)	2.54
DBW-17	17.13 (17.63)	2.83	17.16 (17.4)	1.37	4.36 (4.06)	7.38	4.26 (4.16)	2.40
VL-907	18.36 (18.86)	2.65	17.86 (18.16)	1.65	4.40 (4.16)	5.76	4.20 (4.13)	1.69
SEm±	1.11		0.51		0.12		0.08	
CD at 5%	NS		NS		NS		NS	
CV	10.94		5.12		5.09		3.60	

*Figures in parentheses are respective values for control (open), R= Reduction, I= Increment

Table 5: Biological yield and grain yield of different wheat varieties under poplar based agroforestry system.

Treatments	Biological yield (kg ha^{-1})				Grain yield (kg ha^{-1})			
	2014-15	**% R**	**2015-16**	**% R**	**2014-15**	**% R**	**2015-16**	**% R**
PBW-343	10503.3 (11180)*	6.05	10350 (10896.6)*	5.01	3983.3 (4210)*	5.39	3796.6 (4005)*	7.71
UP-2565	10023.3 (10596.6)	5.41	9763.3 (10293.3)	5.14	3793.3 (3946.6)	3.87	3686.6 (3806.6)	3.15
WH-711	9430 (10080)	6.44	9386.6 (9890)	5.09	3490 (3706.6)	5.82	3376.6 (3513.3)	3.89
DBW-17	9016.6 (9576.6)	5.84	8920 (9636.6)	7.43	3276.6 (3446.6)	4.93	3096.6 (3316.6)	6.63
VL-907	10976.6 (11803.3)	7.0	10570 (11300)	6.46	4220 (4483.3)	5.86	4050 (4243.3)	4.54
SEm±	173.64		102.07		114.05		81.28	
CD at 5%	565.95		332.69		371.72		264.94	
CV	3.01		1.80		5.26		3.90	

*Figures in parentheses are respective values for control (open), R= Reduction

Table 6: Straw yield and harvest index (%) of different wheat varieties under poplar based agroforestry system.

Treatments	Straw yield (kg ha^{-1})				Harvest Index (%)			
	2014-15	**% R**	**2015-16**	**% R**	**2014-15**	**% I**	**2015-16**	**% I**
PBW-343	6520 (6970)*	6.45	6553.3 (6920)*	5.30	37.9 (37.6)*	0.82	36.6 (36.4)*	0.49
UP-2565	6296.6 (6716.6)	6.25	6076.6 (6486.6)	6.32	37.8 (37.2)	1.55	37.7 (36.9)	2.08
WH-711	5940 (6373.3)	6.79	6010 (6376.6)	5.74	37.0 (36.8)	0.51	35.9 (35.4)	1.21
DBW-17	5740 (6130)	6.36	5823.3 (6320)	7.86	36.3 (35.9)	0.97	34.7 (34.5)	0.52
VL-907	6756 (7320)	7.70	6520 (7056.6)	7.59	38.4 (37.9)	1.13	38.3 (37.5)	1.97
SEm±	199.93		94.51		0.91		0.75	
CD at 5%	651.64		308.03		NS		NS	
CV	5.54		2.64		4.23		3.56	

*Figures in parentheses are respective values for control (open), R= Reduction, I= Increment

Table 7: Dry matter accumulation above ground among different wheat varieties at different stages under poplar based agroforestry system during 2014-15

Treatments	2014-15		2014-15		2014-15		2014-15	
	30 DAS	**% R**	**60 DAS**	**% R**	**90 DAS**	**% R**	**Harvesting**	**% R**
PBW-343	15.96 (19.56)*	18.4	165.0 (172.33)*	4.25	400.33 (427.2)*	6.28	875.33 (892.33)*	1.9
UP-2565	18.06 (20.5)	11.9	171.0 (182.0)	6.04	390.63 (414.13)	5.67	842.76 (869.66)	3.09
WH-711	15.5 (16.13)	3.90	163.3 (170.33)	4.12	378.66 (399.43)	5.19	826.66 (847.0)	2.4
DBW-17	13.1 (15.66)	16.34	145.3 (155.66)	6.65	360.26 (394.43)	8.66	790.33 (822.66)	3.92
VL-907	19.6 (21.06)	6.93	179.6 (185.33)	3.09	420.66 (450.43)	6.6	951.3 (981.8)	3.1
SEm±	1.08		6.17		16.57		29.64	
CD at 5%	3.53		20.12		NS		96.61	
CV	11.43		6.48		7.36		5.98	

*Figures in parentheses are respective values for control (open), R= Reduction

Table 8: Dry matter accumulation above ground among different wheat varieties at different stages under poplar based agroforestry system during 2015-16

Treatments	2015-16		2015-16		2015-16		2015-16	
	30 DAS	% R	60 DAS	% R	90 DAS	% R	Harvesting	% R
PBW-343	16.33 (19.66)*	16.93	158.43 (167.53)*	5.43	395.93 (415.66)*	4.74	846.8 (877.56)*	3.5
UP-2565	17.0 (20.0)	15.0	164.4 (170.33)	3.48	371.13 (407.33)	8.88	804.6 (825.53)	2.53
WH-711	14.66 (18.0)	18.55	154.83 (167.03)	7.3	355.33 (385.66)	7.86	751.13 (780.36)	3.74
DBW-17	12.33 (16.0)	22.93	149.06 (155.56)	4.17	344.33 (366.2)	5.97	737.1 (751.7)	1.94
VL-907	18.0 (20.66)	12.87	165.06 (174.73)	5.53	402.66 (426.33)	5.55	905.0 (947.6)	4.49
SEm±	0.55		5.11		16.82		22.62	
CD at 5%	1.81		NS		NS		73.73	
CV	6.166		5.59		7.79		4.84	

*Figures in parentheses are respective values for control (open), R= Reduction

Acknowledgement

The authors are thankful to the HOD (Agroforestry section), Department of Agronomy, G.B. Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand for providing seed material and facilities for conducting research.

References

1. Alka M, Rashmi A, Swami SL. Productivity of soybean and wheat under five promising clones of *Populus deltoides* in agri silviculture system. Plant Archive, 2006; 6(2):567-571.
2. Auclair D, Dupraz C. (eds.), Agroforestry for sustainable Land- Use. Dordrecht: Kluwer Acedemic. 1999, 266.
3. Bisht N, Sah VK, Tewari SK, Singh V, Lavania SK, Banga A. Studies on tree crop interaction under poplar based agroforestry system. Holistic Development of Agroforestry, (Ed) Tewari, SK Sah, VK Lavania, SK, 2016, 273-280.
4. Chauhan SK, Gupta N, Walia R, Yadav S, Chauhan R, Mangat PS. Biomass and carbon sequestration potential of poplar- wheat intercropping system in irrigated agro-ecosystem in India. J. of Agricultural Sciences and Technology, 2011; 1:575-586.
5. Das DK, Chaturvedi OP. Structure and function of *Populus deltoides* agroforestry system in eastern India: 1 Dry matter dynamics. Agroforestry Systems, 2005; 65(3):215-221.
6. Eskandari H, Ghanbari A. Effect of different planting pattern of wheat (*Triticum aestivum*) and bean (*Vicia faba*) on grain yield, dry Matter production and weed biomass. Notulae Scientia Biologicae, 2010; 2(4):111-115.
7. Fang S, Xu X, Yu X, Li Z. Poplar in wetland agro forestry: A case study of ecological benefits, site productivity, and economics', Wetlands Ecology and Management. 2005; 13:93-104.
8. Gliessman SR. Agroecology: The ecology of sustainable food systems, 2nd ed. Boca Raton, FL: CRC Press/Taylor & Francis, 2007.
9. Joshi PC, Prakash O. Allelopathic effects of litter extract of some tree species on germination and seedling growth of agricultural crops. Proceedings of the First National Symposium on Allelopathy in Agro ecosystems, P. Tauro and S.S. Narwal editors., Indian Society of Allelopathy, CCS Haryana Agricultural University, Hisar, India. 1992, 127-128.
10. Kumar BM. Agroforestry: the new old paradigm for Asian food security. J. Tropical Agriculture. 2006; 44(1-2):1-14.
11. Kumar A, Singh V, Tewari SK, Sah VK, Singh AK. Comparative study of different wheat varieties under poplar based agroforestry systems. Thesis Msc. (Ag) (Agroforestry), G.B Pant University of Agriculture and Technology, Pantnagar, Uttarakhand. 2015.
12. Kundu S. Performance of wheat in the radiation climate of agroforestry system under shallow water table conditions. Thesis, M.Sc. G.B. Pant University of Agriculture and Technology, Pantnagar, U.P. 1994, 124.
13. Mishra A, Swamy SL, Bargali SS, Singh AK. Tree Growth, Biomass and Productivity of Wheat under Five Promising Clones of *Populus deltoides* in Agrisilviculture System. Intn. J. Ecol. Environ. Sci. 2010; 36(2-3):167-174.
14. Nair PKR. Soil Productivity Aspects of Agroforestry. ICRAF, Nairobi, Kenya. 1984, 11.
15. Nandal DPS, Dhillon A. Allelopathic effect of poplar (*Populus deltoides* Bartr. Ex. Marsh): An Assessment on the response of wheat varieties under laboratory and field conditions. Indian J. Agroforestry, 2007; 9(2):125-127.
16. Ralhan PK, Singh A, Dhanda RS. Performance of wheat as intercrop under poplar (*Populus deltoides* Bartr) plantations in Punjab. Agroforestry Systems. 1992; 19:217-222.
17. Rao NS, Reddy PC. Studies on inhibitory effect of *Eucalyptus* (hybrid) leaf extracts on the germination of certain crops. *Indian Forester*. 1984; 110(2):5158.
18. Sarvade S, Mishra HS, Kaushal R, Chaturvedi S, Tewari Salil, Jadhav TA. Performance of wheat (*Triticum aestivum* L.) crop under different spacings of trees and fertility levels. African Journal of Agricultural Research, 2014; 9(9):866-873.

19. Schöll LV, Nieuwenhuis R. Soil fertility management, Agrodok *2*, Netherland: Agromisa foundation. 2004, 22-23.
20. Singh C, Dadhwal KS, Dhiman RC, Raj Kumar, Avasthe RK. Allelopathy effects of *Paulownia* and poplar on wheat and maize crops under agroforestry systems in Doon Valley. Indian Forester. 2012; 138(11):142-144.
21. Singh RC, Pathak PS. Growth and production of pigeon pea under *Acacia tortilis* canopy in an Agri-silviculture system. Range Management and Agroforestry, 1993; 14(2):171-178.
22. Somarriba E, Kass D, Ibrahim M. Definition and Classification of Agroforestry Systems' in Ibrahim, M., Beer, J. (ed.) Agroforestry Prototypes for. Belize. Agroforestry Project. CATIE (Tropical Agricultural Research and Higher Education Center), Costa rica, 1998, 3.
23. Tomar SK, Singh HP, Ahlawat IPS. Dry matter accumulation and nitrogen uptake in wheat (*Triticum aestivum*) based intercropping systems as affected by nitrogen fertilizer. Indian J. Agron. 1997; 42(1):33-37.
24. Tripathi MK. Saini BC, Chaturvedi S. Growth and yield of intercropped wheat under *Salix-Dalbergia* agroforestry system. Annals of Biology. 2006; 22(2):189.
25. Wnuk A, Gorny AG, Bocianowski J, Kozak M. Visualizing harvest index in crops. Communications in Biometry and Crop Science. 2013; 8(2):48–59.