

# Effect of nutrient and spacing on growth and biomass production in poplar under nursery condition

## ABSTRACT

Nutrient management is one of the prime factors which play a pivotal role on the growth, development and successful completion of life cycle in all green plants. It is very essential to establish alternate and fast growing tree species to meet the raw material demand of various wood based industries. Poplar occupies an important place amongst fast growing species due to their multiple uses as an industrial raw material in pulp and paper. In this study, effect of different spacing (60×60 cm, 70×30 cm and 80×30 cm) and fertilizer levels (N<sub>1</sub>= N<sub>0</sub> P<sub>0</sub> K<sub>0</sub> (Control), N<sub>2</sub>= N<sub>100</sub> P<sub>50</sub> K<sub>25</sub>, N<sub>3</sub>= N<sub>150</sub> P<sub>75</sub> K<sub>37.5</sub>, N<sub>4</sub>= N<sub>200</sub> P<sub>100</sub> K<sub>50</sub>, N<sub>5</sub>= N<sub>250</sub> P<sub>75</sub> K<sub>62.5</sub> and N<sub>6</sub>= N<sub>0</sub> P<sub>0</sub> K<sub>0</sub> + Biofertilizers) on growth of poplar under nursery condition during 2019 and 2020. The performances of growth were influenced by N, P and K at different levels. All the growth characters viz. sprouting per cent, basal diameter, leaf area and total biomass in general increased significantly with increased spacing during both the years. However, plant height and chlorophyll content showed differential response and increased significantly with decrease in spacing. Fertilizer application significantly improved the growth of poplar clones in terms of basal diameter, plant height, leaf area, chlorophyll content and total biomass over control. In poplar nursery, the growth was significantly higher for 60 × 60 cm spacing as compared to other spacings of poplar. The highest growth in poplar was registered under the application of N<sub>200</sub> P<sub>100</sub> K<sub>50</sub> with 60×60 cm spacing.

**Keywords:** - Poplar, Nitrogen, Phosphorus, Potassium, Growth performances, spacing, nutrient and biomass production

## INTRODUCTION

Poplar (*Populus deltoides*) is a commercially important fast growing tree species that belongs to family Salicaceae. In India, it spread over 0.27 million ha area mostly in states like Haryana, Punjab, Uttrakhand, Uttar Pradesh and some parts of Bihar, etc (ICFRE, 2016). Poplar is favoured by farmers due to its higher productivity, vegetative propagation and multiplicity of uses of its wood. The cultivation of poplar has generated huge employment in the rural areas of

India and has improved the overall rural economy (Chavan and Dhillon, 2019). Its soft attractive, strong and easily workable wood is suitable for manufacturing matches, furniture, packing cases, plywood, sports goods, pulp and paper, rayon, fiberboard and pencils (Sidhu and Dhillon, 2007; Handa *et al.*, 2020). Nutrient management is one of the prime factors which play a pivotal role in the growth and development of plants. Application of organic and inorganic fertilizers produced significantly higher fresh and dry weight of both above and below ground biomass. The growth performances was influenced significantly by N, P and K at different levels in Poplar (Saravanakumar and Shanthinipriya, 2017). The application of fertilizers about 20 cm from the poplar cuttings enhanced growth compared to untreated cuttings and was about twice as effective as the banding of fertilizers (Van den Driessche, 1999). Similarly, the application of fertilizers applied to the base of a planted tree positively influenced its growth (Bilodeau-Gauthier, 2011). Since poplar is sensitive to competing vegetation (Fang *et al.*, 2008), fertilizing the whole area increases the growth of competing vegetation. Durai *et al.* (2009) emphasized that the deliberately planted trees for enhanced economic gains will certainly exploit more natural resources including inherent nutrients of soil profile as compared to sole crop. The effect of fertilization on poplar during its growing phase applied as a single nutrient in the nursery has been known to be positive. However, detail of appropriate nutrient combinations and specific amounts varies according to soil types and clones' responses to fertilization are not known. Therefore, the present study was conducted to assess the effect of NPK and spacing requirement quality nursery stock and to study utilization of nutrients by poplar nursery

## **MATERIALS AND METHODS**

### **Study Area**

The present experiment was carried out in the research area of Forestry department, CCS Haryana Agricultural University Hisar (Haryana) during 2019 and 2020. Geographically, the experimental site is situated at 29° 09' N latitude and 75° 43' E longitude at an elevation of 215.2 m above mean sea level situated in the semi-arid region of north-western India.

### **Data Collection**

In this study, consisted of six level of nutrient levels cm) *viz.*, (N<sub>1</sub>= N<sub>0</sub> P<sub>0</sub> K<sub>0</sub> (Control), N<sub>2</sub>= N<sub>100</sub> P<sub>50</sub> K<sub>25</sub>, N<sub>3</sub>= N<sub>150</sub> P<sub>75</sub> K<sub>37.5</sub>, N<sub>4</sub>= N<sub>200</sub> P<sub>100</sub> K<sub>50</sub>, N<sub>5</sub>= N<sub>250</sub> P<sub>75</sub> K<sub>62.5</sub> and N<sub>6</sub>= N<sub>0</sub> P<sub>0</sub> K<sub>0</sub> + Biofertilizers) with three spacing (60×60 cm, 70×30 cm and 80×30 on growth of poplar under nursery condition during 2019 and 2020. Experiment was laid out in split plot design with three

replications having spacing in the main plot and nutrient levels in sub-plot. Cuttings were treated with Aldrin as an ant termite measure. (250ml Aldrex 30 E.C. should be thoroughly mixed in 100 ltr. And cutting was allowed to keep for 10 min) Thereafter, the cuttings was treated with Emisan – an organ mercurial fungicide (250 g Emisan-6 in 100 ltr. Water) and kept submerged for 10 minutes. Cutting of uniform size of clone were planted in the first week of February 2019 and 2020. Nitrogen was applied in the form of urea (46 percent N), P as di-ammonium phosphate (46 percent  $P_2O_5$  and 18 percent N) and K as murate of potash (60 percent  $K_2O$ ).complete doses of phosphorus, potash and 1/3 doses of total nitrogen requirement in the second week of June and 1/3 doses of total nitrogen requirement in the first week of August. Biofertilizers treatment of Poplar cutting was treated with a solution of 100 ml Phospotica and Azotica (CCSHAU made) in 25 litre water for 15 minute.

The observation on growth parameter Cutting sprouting percentage, Plant height, Collar diameter, Leaf area, Chlorophyll content, and total biomass production were recorded in the months of January 2019 and 2020. The biomass of harvested trees was divided into two categories *i.e.*, aboveground biomass (stem, branch and leaf) and belowground biomass (roots). The stem of felled trees further divided into standard log size of 2.64 m, depending upon straightness and knots. The fresh weight of each log was measured in kilogram (kg) with the help of electronic digital balance (error  $\pm 5$  g) and recorded. The representative samples from log of five trees were collected and were further kept in the oven at a temperature of  $70\pm 2$  °C till constant weight to calculate the oven dry weight of log specimens/samples. Branch biomass without leaves was calculated from trees. Branches of selected trees were separated from the stem and weighed immediately with the help of electronic digital balance (error  $\pm 5$  g) in the field to get the total fresh weight of branch of each tree. The known weight of representative branch samples (3 replicates) was taken air dried, and then samples were kept in oven ( $70\pm 2$  °C) till the constant weight to calculate the dry biomass weight of branch of each tree. In case of leaves, five representative samples of fresh leaves were weighed; air dried and kept in oven at  $70\pm 2$  °C to get dry leaves biomass of each tree. The following formulae were used to determine dry matter content (%) of samples and total dry biomass ( $kg\ tree^{-1}$ ).

Where: TFB= Total fresh biomass of component; DMC= dry matter content (%)

Where:  $ds_1$ ,  $ds_2$  and  $ds_3$ : Oven dry weight of components of first, second and third sample, respectively;  $fs_1$ ,  $fs_2$  and  $fs_3$ : Fresh weight of components of sample one, two and three, respectively

The BGB of trees consist of root biomass, is one of the labour-intensive and complex work. In the present study, stump considered as the above-ground base part of the stem which would remain with root system after a tree had cut under normal felling practices excluding root biomass. The stump of harvested trees was excavated with the help of axe, spade, shovel and pickaxe from the area of 0.5–1m<sup>3</sup> around the tree stump.

## RESULTS AND DISCUSSION

### Sprouting of cutting

The data depicted in Table 1 show that sprouting percentage of poplar cutting after one month of raising nursery during 2019 and 2020. It was observed that higher sprouting percentage (91.57) in cuttings planted at 60×60 cm ( $S_1$ ) than 80x30 cm (89.83) and 70×30 cm (89.09) spacings but the differences were statistically non-significant during 2019. However, almost similar pattern in sprouting of cuttings was also recorded with minor variation during 2020. The maximum percent sprouting was observed in 60×60 cm (90.99) followed by 70×30 cm (89.63) and 80x30 cm (89.29). There was clear liner positive relationship of spacing to sprouting per cent. The results of present study are similar with the findings of Sofi et al. (2020) in which they reported higher sprouting (97.08%) in wider spacing as compared to narrow spacing. However, sprouting percentage increased significantly with increasing nutrient levels upto  $N_3$  ( $N_{150} P_{75} K_{37.5}$ ) over control ( $N_1$ ) during both the years of study. The maximum cutting sprouting of 92.09 and 92.67 % was found in  $N_3$  ( $N_{150} P_{75} K_{37.5}$ ), while minimum of 87.31 and 88.24 % in control ( $N_1$ ) during 2019 and 2020, respectively. The biofertilizers effect on sprouting of cutting was found positive during both the years of study but the differences were statically non significant between control and biofertilizers treatment. The interaction effect between spacing and nutrients levels on sprouting percentage of poplar cuttings was found significant during both the years. It is evident from the data that the sprouting percentage of poplar plants increased significantly with increasing levels of nutrients upto  $N_3$  ( $N_{150} P_{75} K_{37.5}$ ), the maximum sprouting percentage of 98.40 and 98.45 of poplar cutting during 2019 and 2020, respectively was recorded in 60x60 cm spacing with applied fertilizer level of  $N_3$  ( $N_{150} P_{75} K_{37.5}$ ) followed by 70x30 cm spacing with same fertilizer levels. These results are agreement with Sofi *et al.* (2020) that

highest (96.50 %) sprouting observed with application of 75 kg nitrogen ha<sup>-1</sup>. Similarly, Damgaard *et al.* (2013) also reported that increasing levels of fertilizer enhanced the sprouting of cutting in *Fesuca ovina*.

**Table 1: Effect of different spacings and nutrient levels on per cent sprouting of poplar cutting in nursery**

Fertilizer(Nutrient) level	Sprouting of cutting (%)							
	2019				2020			
	S <sub>1</sub> (60×60 cm)	S <sub>2</sub> (70×30 cm)	S <sub>3</sub> (80×30 cm)	Mean	S <sub>1</sub> (60×60 cm)	S <sub>2</sub> (70×30 cm)	S <sub>3</sub> (80×30 cm)	Mean
N <sub>1</sub> = (Control)	82.53	86.71	92.68	87.31	84.86	84.76	95.11	88.24
N <sub>2</sub> = N <sub>100</sub> P <sub>50</sub> K <sub>25</sub>	95.76	84.35	90.28	90.13	95.83	84.29	87.78	89.30
N <sub>3</sub> = N <sub>150</sub> P <sub>75</sub> K <sub>37.5</sub>	98.40	95.97	81.91	92.09	98.45	96.33	83.22	92.67
N <sub>4</sub> = N <sub>200</sub> P <sub>100</sub> K <sub>50</sub>	89.05	90.29	92.21	90.52	88.06	90.95	90.67	89.89
N <sub>5</sub> = N <sub>250</sub> P <sub>75</sub> K <sub>62.5</sub>	95.03	85.38	94.76	91.73	91.11	88.57	94.67	91.45
N <sub>6</sub> = Biofertilizers	88.31	91.12	86.53	88.65	87.64	92.86	84.33	88.28
Mean	<b>91.57</b>	<b>89.09</b>	<b>89.83</b>		<b>90.99</b>	<b>89.63</b>	<b>89.29</b>	
CD (spacing) at 5 %	NS				NS			
CD (fertilizer levels) at 5 %	1.71				2.06			
fertilizer levels at same level of spacing	3.28				3.68			
spacing at same level of fertilizer levels	3.50				3.49			

### Plant height and collar diameter

The effect of spacing and fertilizer levels on sprout /plant height of poplar in nursery after 3, 6 and 9 months after planting (MAP) of cutting during 2019 and 2020 is presented in Table 2. Plant height/sprout length increased with successive stages of growth. Significantly higher plant height was recorded in 70×30 cm spacing than 60×60 cm and 80x30 cm after 6 and 9 MAP however, after 3 MAP the variation in plant height/sprout length was found non significant differences between 70x30 cm and 80x30 cm spacing in nursery in present study during 2019. In contrast during 2020, the plant height exhibited statistically significant variations in different

spacings under study after 3MAP of cuttings. In present study, the sprouts/plant height of poplar in nursery registered significantly higher values in 70x30 cm than other spacing at different stages/intervals of growth during both the years. However, plant height exhibited statistical at par values after 6 and 9 MAP between 60x60 cm and 80x30 cm spacings during 2020 and at 6 and 9 MAP during 2019. The mean plant height/sprout length of poplar at different stages/intervals of growth in nursery was found higher during 2020 as compared to 2019. In fast growing hardwoods, tree height may increase, decrease, or remain unchanged with increasing spacing between trees (Alcorn *et al.* 2007; Debell *et al.* 1996; Fang *et al.* 1999; Kerr 2003; Pinkard and Neilsen 2003). Height growth plays an important role in morphological acclimation to light competition (Lanner, 1985). However, the dbh was found significantly higher in S<sub>1</sub> (60x60 cm) followed by 80x30 cm and 70x30 cm. However, basal diameter of sprout/plant after 3, 6 and 9 MAP was found statistical at par between 70x30 and 80x30 cm spacings during 2020 and 6 and 9 MAP during 2019. The mean basal diameter of sprout/plant of poplar in nursery at different stages/intervals of growth was found higher during 2020 as compared to 2019 may be due to availability of more space for plants and consequently less competition for moisture, sun light and nutrients in nursery. The highest dbh growth under 60x60 cm spacing may be attributed due to availability of more space to each plant in different spacing. These results are also in close conformity with the findings of Singh *et al.* (2001). Similar trends in poplar growth under different spacings with slight variable values have been reported by several research workers (Nissen *et al.*, 2001; Dogra *et al.*, 2007; Khan and Chaudhary, 2007; Chauhan *et al.*, 2012).

**Table 2 Effect of different spacings and fertilizer levels on sprout length/plant height (m) of poplar after plantation of cuttings at 3 months interval in nursery**

Fertilizer Levels	Plant height/sprout length (m) after plantation of cuttings at 3 months interval																							
	2019												2020											
	3 MAP				6 MAP				9 MAP				3 MAP				6 MAP				9 MAP			
	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	Mean	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	Mean	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	Mean	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	Mean	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	Mean	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	Mean
N <sub>1</sub>	1.05	1.70	1.60	1.45	3.20	3.66	3.10	3.32	6.10	6.30	6.00	6.13	1.14	1.73	1.49	1.45	3.30	3.30	3.10	3.23	5.22	5.65	5.59	5.49
N <sub>2</sub>	1.40	1.77	1.70	1.62	3.40	3.80	3.40	3.53	6.20	6.40	6.20	6.27	1.65	1.83	1.89	1.79	3.70	3.60	3.30	3.53	5.80	6.40	6.00	6.07
N <sub>3</sub>	1.65	1.80	1.75	1.73	3.50	4.10	3.50	3.70	6.40	6.50	6.50	6.47	1.78	2.08	1.80	1.89	3.70	4.20	3.90	3.93	6.10	6.88	6.40	6.46
N <sub>4</sub>	1.70	1.95	1.83	1.83	3.85	4.40	3.90	4.05	6.60	7.10	6.70	6.80	1.80	2.45	2.10	2.12	3.90	4.44	4.20	4.18	6.70	7.40	6.73	6.94
N <sub>5</sub>	1.6	1.9	1.8	1.79	3.8	4.2	3.8	3.93	5.8	5.3	5.5	5.53	1.6	1.9	2.0	1.88	3.6	4.2	4.0	3.93	6.5	6.7	6.6	6.63

	8	0	0		0	0	0		0	0	0		7	1	6		0	0	0		0	9	0	
N <sub>6</sub>	1.3 3	1.7 7	1.6 2	<b>1.57</b>	3.3 0	3.6 0	3.5 0	<b>3.47</b>	6.0 8	6.2 9	6.1 5	<b>6.17</b>	1.2 7	1.9 5	1.7 5	<b>1.66</b>	3.5 0	3.4 3	3.4 1	<b>3.45</b>	5.9 2	6.0 8	5.8 8	<b>5.96</b>
Mean	<b>1.4</b> 7	<b>1.8</b> 1	<b>1.7</b> 2		<b>3.5</b> 1	<b>3.9</b> 6	<b>3.5</b> 3		<b>5.0</b> 0	<b>6.1</b> 0	<b>5.4</b> 0		<b>1.5</b> 5	<b>1.9</b> 9	<b>1.8</b> 5		<b>3.6</b> 2	<b>3.8</b> 6	<b>3.6</b> 5		<b>6.0</b> 4	<b>6.5</b> 3	<b>6.2</b> 0	
CDat 5%																								
S	0.14			0.28			0.20			0.11			0.15			0.16								
FL	0.21			0.39			0.20			0.18			0.23			0.15								
FL × S	NS			NS			0.37			NS			NS			0.28								
S × FL	NS			NS			0.37			NS			NS			0.28								

N<sub>1</sub>=control, N<sub>2</sub>=N<sub>100</sub>P<sub>50</sub>K<sub>25</sub>, N<sub>3</sub>=N<sub>150</sub>P<sub>75</sub>K<sub>37.5</sub>, N<sub>4</sub>=N<sub>200</sub>P<sub>100</sub>K<sub>50</sub>, N<sub>5</sub>=N<sub>250</sub>P<sub>75</sub>K<sub>62.5</sub>, N<sub>6</sub>=Biofertilizers, S<sub>1</sub>=60 cm × 60 cm, S<sub>2</sub>= 70 cm × 30 cm, S<sub>3</sub>= 80 cm × 30 cm

N×S= nutrient levels at same level of spacing, S×N= spacing at same level of nutrient level

Plant height/sprout length increased significantly with increasing fertilizer level up to N<sub>4</sub> (N<sub>200</sub> P<sub>100</sub> K<sub>50</sub>) during both the consecutive years. Maximum plant height of 6.80 and 6.94 m during 2019 and 2020, respectively after 9 MAP in nursery was recorded with the fertilizer application of N<sub>200</sub> P<sub>100</sub> K<sub>50</sub> (N<sub>4</sub>). However, the higher fertilizer level N<sub>5</sub> (N<sub>250</sub>P<sub>75</sub>K<sub>62.5</sub>) showed inhibitory effect due to which plant height was observed lesser in N<sub>5</sub>(N<sub>250</sub>P<sub>75</sub>K<sub>62.5</sub>) as compared to N<sub>4</sub> (N<sub>200</sub> P<sub>100</sub> K<sub>50</sub>). Minimum plant height was observed in control at different stages of growth. The biofertilizers treatment showed positive response to sprout length/plant height but showed significantly lesser plant height as compared to different chemical fertilizer levels in present study. Similar basal diameter of sprout/plant of poplar in nursery increased significantly with increasing nutrient levels of fertilizer up to N<sub>4</sub> (N<sub>200</sub> P<sub>100</sub> K<sub>50</sub>) during both the years of investigation (Table-3). Data reveal that among the fertilizer levels, maximum basal diameter of 4.47 cm and 5.11 cm was recorded with the fertilizer application of N<sub>4</sub> (N<sub>200</sub>P<sub>100</sub>K<sub>50</sub>) whereas; lowest basal diameter of 3.29 cm and 3.50 cm in control during 2019 and 2020 respectively was recorded at 9 MAP. However, basal diameter of sprout/plant of poplar in different spacing in nursery did not show further increase with the increase in fertilizer level of N<sub>5</sub> N<sub>250</sub>P<sub>75</sub>K<sub>62.5</sub> (N<sub>5</sub>) during both 2019 and 2020 may be due to inhibitory effect of higher concentration of available nutrients. The results of present study are similar with the findings of Singh *et al.* (2001), Kumari *et al.* (2017), Faiz and Singh (2008) where they have recorded application of fertilizer N<sub>200</sub>P<sub>100</sub>K<sub>50</sub> kg ha<sup>-1</sup> in poplar plantation registered higher plant height. The increase in plant height and collar diameter with increasing nutrients levels might be due to adequate quantities and balanced proportion of plant nutrients supplied to the poplar plants as per need resulting in

favourable increase in growth parameters (Gola Kiya, 1988). The highest level N<sub>250</sub> P<sub>75</sub> K<sub>62.5</sub> of fertilizers used in the study did not increase collar diameter and height of plants this may be attributed to the fact that the higher amount of fertilizers applied might have lead to the over nutrient status of the site, than required by plants. Favourable effect of fertilizers on the growth of poplar in nursery has also been reported by Sheedy (1976) and Dimitrov *et al.* (1976), Deol and Khosla (1983), Mohan (1992) and Gangoo *et al.* (1997).

**Table 3** Effect of different spacings and fertilizer levels on basal diameter (cm) of sprout/plant of poplar cuttings at 3 months interval in nursery

Fertilizer Levels	basal diameter (cm) after plantation of cuttings at 3 months interval																							
	2019												2020											
	3 MAP				6 MAP				9 MAP				3 MAP				6 MAP				9 MAP			
	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	Me an	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	Me an	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	Me an	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	Me an	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	Me an	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	Me an
N <sub>1</sub>	1.15	0.99	1.02	1.05	2.58	2.22	2.39	2.39	3.65	3.00	3.21	3.29	1.21	0.93	1.02	1.05	1.80	2.20	2.18	2.06	3.73	3.22	3.55	3.50
N <sub>2</sub>	1.21	1.00	1.03	1.08	2.84	2.44	2.35	2.54	4.05	3.64	3.89	3.86	1.17	1.06	1.21	1.15	2.96	2.40	2.40	2.59	4.96	4.33	4.00	4.43
N <sub>3</sub>	1.28	1.11	1.12	1.17	2.86	2.51	2.50	2.62	4.51	3.91	4.13	4.18	1.36	1.14	1.32	1.27	3.05	2.55	2.62	2.74	5.51	4.64	4.4	4.85
N <sub>4</sub>	1.36	1.18	1.21	1.25	3.08	2.56	2.70	2.78	5.01	4.12	4.28	4.47	1.41	1.24	1.38	1.35	3.25	2.67	2.80	2.91	5.64	4.8	4.9	5.11
N <sub>5</sub>	1.21	1.15	1.24	1.20	3.01	2.55	2.50	2.69	4.8	4.08	4.20	4.36	1.37	1.25	1.37	1.33	3.03	2.65	2.74	2.81	5.64	4.76	4.8	5.07
N <sub>6</sub>	1.11	1.11	1.03	1.09	2.77	2.33	2.45	2.52	4.00	3.78	3.82	3.87	1.11	1.09	1.10	1.10	2.96	2.58	2.50	2.68	4.5	3.96	4.06	4.17
Mean	1.22	1.09	1.11		2.85	2.44	2.48		4.34	3.76	3.92		1.27	1.12	1.23		2.84	2.51	2.54		5.00	4.29	4.28	
<b>CD at 5%</b>																								
S	0.10				0.13				0.15				0.11				0.15				0.16			
FL	0.09				0.11				0.10				0.18				0.23				0.15			
FL × S	NS				NS				0.21				NS				NS				0.28			
S × FL	NS				NS				0.22				NS				NS				0.28			

N<sub>1</sub>=control, N<sub>2</sub>=N<sub>100</sub>P<sub>50</sub>K<sub>25</sub>, N<sub>3</sub>=N<sub>150</sub>P<sub>75</sub>K<sub>37.5</sub>, N<sub>4</sub>=N<sub>200</sub>P<sub>100</sub>K<sub>50</sub>, N<sub>5</sub>= N<sub>250</sub>P<sub>75</sub>K<sub>62.5</sub>, N<sub>6</sub>=Biofertilizers, S<sub>1</sub>=60 cm × 60 cm, S<sub>2</sub>= 70 cm × 30 cm, S<sub>3</sub>= 80 cm × 30 cm

N×S= nutrient levels at same level of spacing, S×N= spacing at same level of nutrient levels

### Chlorophyll content

Chlorophyll content was measured with the help of an instrument SPAD 502. Chlorophyll is the pigment involved in the photosynthesis for harvesting the light and absorbing photons, which transfer the excitation energy to the photosynthetic reaction center. Chlorophyll content did not differ significantly due to different spacings at all the stages during both the years except 3 MAP during 2020. Maximum chlorophyll content was found in closer spacing S<sub>2</sub> (70×30 cm) while minimum was recorded in wider spacing S<sub>1</sub> (60×60 cm) at different stages during both the years (Table-4). The similar findings were recorded by Yanjun *et al.* (2018) in *Setariaitalic* where chlorophyll content of leaves was found higher in decreasing plant spacing in nursery.

**Table 4 Effect of different spacings and fertilizer levels on leaf chlorophyll content (SPAD unit) of poplar cuttings at 3 months interval in nursery**

Fertilizer Levels	Chlorophyll content (SPAD unit) after plantation of cuttings at 3 months interval																							
	2019												2020											
	3 MAP				6 MAP				9 MAP				3 MAP				6 MAP				9 MAP			
	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	Mean	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	Mean	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	Mean	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	Mean	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	Mean	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	Mean
N <sub>1</sub>	34.60	35.23	33.50	<b>34.45</b>	50.90	50.70	51.93	<b>51.18</b>	38.80	37.00	38.70	<b>38.17</b>	35.70	33.33	37.40	<b>35.48</b>	50.12	54.56	50.00	<b>51.56</b>	40.80	38.00	39.00	<b>39.27</b>
N <sub>2</sub>	38.10	38.60	39.20	<b>38.63</b>	51.80	54.30	52.40	<b>52.83</b>	41.70	42.80	41.80	<b>42.10</b>	37.30	39.60	38.10	<b>38.33</b>	54.39	56.90	53.10	<b>54.80</b>	42.66	41.70	43.21	<b>42.52</b>
N <sub>3</sub>	39.90	39.70	40.40	<b>40.00</b>	57.60	57.60	54.80	<b>56.67</b>	43.90	44.80	43.60	<b>44.10</b>	38.30	42.83	40.04	<b>40.39</b>	55.90	57.00	56.00	<b>56.30</b>	43.44	49.54	43.30	<b>45.43</b>
N <sub>4</sub>	41.70	44.60	43.81	<b>43.37</b>	59.10	62.12	63.45	<b>61.55</b>	47.80	50.80	49.50	<b>49.37</b>	41.80	46.72	42.67	<b>43.73</b>	64.10	60.10	63.70	<b>62.63</b>	48.72	49.00	47.90	<b>48.54</b>
N <sub>5</sub>	40.60	43.30	40.56	<b>41.49</b>	57.70	60.50	59.13	<b>59.11</b>	45.80	45.90	46.40	<b>46.03</b>	38.40	44.16	45.12	<b>42.56</b>	58.00	56.90	58.44	<b>57.78</b>	45.78	47.23	48.00	<b>47.00</b>
N <sub>6</sub>	33.10	37.88	38.98	<b>36.65</b>	48.60	52.90	52.20	<b>51.23</b>	41.10	40.60	40.30	<b>40.67</b>	34.60	38.14	37.67	<b>36.80</b>	49.24	53.90	52.00	<b>51.71</b>	41.50	39.10	42.80	<b>41.13</b>
<b>Mean</b>	<b>38.00</b>	<b>39.89</b>	<b>39.41</b>		<b>54.28</b>	<b>56.35</b>	<b>55.65</b>		<b>43.18</b>	<b>43.65</b>	<b>43.38</b>		<b>37.68</b>	<b>40.80</b>	<b>40.17</b>		<b>55.29</b>	<b>56.56</b>	<b>55.54</b>		<b>43.82</b>	<b>44.09</b>	<b>44.04</b>	
CDat 5%																								
S	NS				NS				NS				NS				NS				NS			
FL	2.49				2.98				NS				3.11				2.31				2.32			
FL × S	NS				NS				NS				NS				NS				NS			
S × FL	NS				NS				NS				NS				NS				NS			

N<sub>1</sub>=control, N<sub>2</sub>=N<sub>100</sub>P<sub>50</sub>K<sub>25</sub>, N<sub>3</sub>=N<sub>150</sub>P<sub>75</sub>K<sub>37.5</sub>, N<sub>4</sub>=N<sub>200</sub>P<sub>100</sub>K<sub>50</sub>, N<sub>5</sub>= N<sub>250</sub>P<sub>75</sub>K<sub>62.5</sub>, N<sub>6</sub>=Biofertilizers, S<sub>1</sub>=60 cm × 60

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cm, S<sub>2</sub>= 70 cm × 30 cm, S<sub>3</sub>= 80 cm × 30 cm

N×S= nutrient levels at same level of spacing, S×N= spacing at same level of nutrient levels

Chlorophyll content of poplar revealed that nutrients level in different doses had significant effect on poplar chlorophyll content during both years. Data reveals that among the nutrients maximum chlorophyll content was recorded in treatment (N<sub>250</sub>P<sub>75</sub>K<sub>62.5</sub>) followed by (N<sub>200</sub>P<sub>100</sub>K<sub>50</sub>), (N<sub>150</sub>P<sub>75</sub>K<sub>37.5</sub>), (N<sub>100</sub>P<sub>50</sub>K<sub>25</sub>) and the lowest chlorophyll content was recorded in control at different stages of growth during both years. It may be due to the fact that optimum availability of nitrogen plays a vital role in cell division and the formation of active photosynthetic pigment including chlorophyll and green pigment in leaves depend also on phosphorous concentration (Bojović and Stojanović, 2006). The similar findings were recorded by Tajul *et al.* (2013) who reported the highest chlorophyll SPAD value were found with application of N<sub>220</sub> kg ha<sup>1</sup> and concluded that there is a close relationship between the fertilization with nitrogen and chlorophyll content in the leaves and results of present investigation are in conformity with the results of several research workers (Odabas, 1981; Neto *et al.*, 2011; Lei *et al.*, 2010 and Uysal *et al.* 2013).

### **Leaf area**

The data pertaining to leaf area of poplar in different spacing showed that maximum leaf area was found in plants growing in S<sub>1</sub> (60×60 cm) and minimum in S<sub>2</sub> (70×30 cm) at all stages of observations during both years. The results indicate that the leaf area was higher in plants growing in wider spacing which is in harmony with the findings of Khan and Chaudhary (2007) and Sofi *et al.* (2020) who reported an increase in leaf area in the wider spacings of poplar in field.

The data presented in Table 5 related that that nutrients level had significant effect on leaf area of poplar in nursery during both years. Maximum leaf area was recorded in treatment (N<sub>250</sub>P<sub>75</sub>K<sub>62.5</sub>) and the lowest leaf area was recorded in control at different stages of observations during both years. Leaf area increased with increase in fertilizer levels during both the years of investigation. Similar findings have been reported in Poplar by Singh *et al.* (2019) where they reported that maximum mean leaf area (369.99 cm<sup>2</sup>) was recorded in treatment (N<sub>150</sub>P<sub>100</sub>K<sub>50</sub>). Faiz and Singh (2008), Saravanakumar and Shanthinipriya (2017) and Singh *et al.* (2018) also reported the increased in leaf area due to the optimal quantity of Nitrogen, Phosphorus and Potassium fertilizers.

**Table 5** Effect of different spacings and fertilizer levels on leaf area (cm<sup>2</sup>) of poplar cuttings at 3 months interval in nursery

Fertilizer levels	leaf area (cm <sup>2</sup> ) after plantation of cuttings at 3 months interval																							
	2019												2020											
	3 MAP				6 MAP				9 MAP				3 MAP				6 MAP				9 MAP			
	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	Mean	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	Mean	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	Mean	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	Mean	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	Mean	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	Mean
N <sub>1</sub>	118.35	119.40	137.44	<b>125.06</b>	318.41	280.41	296.56	<b>298.46</b>	295.37	266.81	277.45	<b>279.88</b>	130.41	120.00	128.24	<b>126.22</b>	314.17	292.19	301.26	<b>302.54</b>	296.37	274.32	295.37	<b>288.69</b>
N <sub>2</sub>	146.32	130.00	166.48	<b>147.60</b>	322.53	305.14	309.42	<b>312.36</b>	301.78	285.06	288.82	<b>291.89</b>	158.07	150.02	153.60	<b>153.90</b>	319.58	311.98	313.38	<b>314.98</b>	300.68	282.40	288.09	<b>290.39</b>
N <sub>3</sub>	153.66	150.00	183.97	<b>162.54</b>	328.53	310.02	318.55	<b>319.03</b>	306.29	283.35	294.91	<b>294.85</b>	158.49	154.49	155.23	<b>156.07</b>	328.65	312.98	317.76	<b>319.80</b>	308.29	282.45	286.94	<b>292.56</b>
N <sub>4</sub>	168.26	180.38	209.34	<b>185.99</b>	329.93	323.70	326.47	<b>326.70</b>	310.13	301.34	305.61	<b>305.69</b>	185.47	180.55	181.37	<b>182.46</b>	330.96	320.46	326.03	<b>325.82</b>	312.19	292.71	306.95	<b>303.95</b>
N <sub>5</sub>	183.59	170.44	191.69	<b>181.91</b>	339.29	334.13	334.46	<b>335.96</b>	318.63	306.67	306.78	<b>310.70</b>	199.00	172.27	188.11	<b>186.46</b>	343.94	327.36	335.10	<b>335.47</b>	321.21	299.42	312.28	<b>310.97</b>
N <sub>6</sub>	133.51	128.57	173.30	<b>145.13</b>	321.29	291.28	301.59	<b>304.72</b>	294.57	273.94	279.35	<b>282.62</b>	146.76	134.57	136.47	<b>139.26</b>	318.66	291.78	297.94	<b>302.79</b>	291.97	279.63	290.30	<b>287.30</b>
Mean	<b>150.62</b>	<b>146.47</b>	<b>177.04</b>		<b>326.66</b>	<b>307.45</b>	<b>314.51</b>		<b>304.46</b>	<b>286.19</b>	<b>292.15</b>		<b>163.03</b>	<b>151.98</b>	<b>157.17</b>		<b>325.99</b>	<b>309.46</b>	<b>315.25</b>		<b>305.12</b>	<b>285.16</b>	<b>296.65</b>	
CDat 5%																								
S	4.01				7.17				6.80				6.53				5.37				12.19			
FL	3.78				10.01				9.02				8.88				8.47				7.94			
FL × S	NS				NS				NS				NS				NS				NS			
S × FL	NS				NS				NS				NS				NS				NS			

N<sub>1</sub>=control, N<sub>2</sub>=N<sub>100</sub>P<sub>50</sub>K<sub>25</sub>, N<sub>3</sub>=N<sub>150</sub>P<sub>75</sub>K<sub>37.5</sub>, N<sub>4</sub>=N<sub>200</sub>P<sub>100</sub>K<sub>50</sub>, N<sub>5</sub>=N<sub>250</sub>P<sub>75</sub>K<sub>62.5</sub>, N<sub>6</sub>=Biofertilizers, S<sub>1</sub>=60 cm × 60 cm, S<sub>2</sub>=70 cm × 30 cm, S<sub>3</sub>=80 cm × 30 cm

N×S= nutrient levels at same level of spacing, S×N= spacing at same level of nutrient levels

### Total biomass

The data on total dry biomass production by poplar plants in different spacing in Table 6 showed significant variation for different spacing with maximum was found in S<sub>1</sub> (60×60 cm) and minimum was in S<sub>2</sub> (70×30 cm) during both the years. Total above and below ground (root) biomass of poplar plants increased significantly with wider spacing may be attributed to the availability of more space and more amounts of nutrients to individual's plants under wider spacing. Increase in plant biomass at wider spacing has also been reported by Singh and Sharma

(1984) and Singh *et al.* (2001) in poplar and also with Lal (1993) in *Ulmus laevigata*, Sofi (2005) in *Cedrus deodara*, Hegazy *et al.* (2008) in *Conocarpus erectus* and Vidhya (2012) in *Casuarina* hybrid.

**Table 6 Effect of different spacings and fertilizer levels on total dry biomass (g) of poplar plants in nursery during 2019 and 2020**

Fertilizer levels	Total biomass (g)																							
	2019												2020											
	Above Ground Biomass (g)				Below Ground Biomass (g)				Total Biomass (g)				Above Ground Biomass (g)				Below Ground Biomass (g)				Total Biomass (g)			
	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean
N <sub>1</sub>	1328	995	1008	<b>1110</b>	530	408	370	<b>439</b>	1859	1403	1388	<b>1550</b>	1722	1273	1200	<b>1398</b>	493	339	338	<b>407</b>	2215	1612	1589	<b>1806</b>
N <sub>2</sub>	1853	1414	1550	<b>1606</b>	828	549	448	<b>623</b>	2682	1959	2048	<b>2230</b>	2028	1466	1607	<b>1701</b>	741	403	606	<b>592</b>	2770	1866	2244	<b>2293</b>
N <sub>3</sub>	1925	1685	1723	<b>1778</b>	900	540	550	<b>648</b>	2826	2231	2223	<b>2427</b>	2186	1629	1927	<b>1914</b>	870	479	756	<b>702</b>	3056	2108	2683	<b>2616</b>
N <sub>4</sub>	2945	2286	2276	<b>2502</b>	1100	659	507	<b>782</b>	4079	2937	2874	<b>3296</b>	5999	1976	2083	<b>3353</b>	1226	624	900	<b>929</b>	7226	2596	3023	<b>4281</b>
N <sub>5</sub>	2265	1857	1858	<b>1993</b>	900	501	511	<b>651</b>	3166	2325	2410	<b>2633</b>	2614	1618	1851	<b>2028</b>	990	500	709	<b>761</b>	3604	2118	2642	<b>2788</b>
N <sub>6</sub>	1852	1380	1508	<b>1580</b>	700	249	482	<b>480</b>	2552	1629	2001	<b>2061</b>	2025	1482	1590	<b>1699</b>	656	390	600	<b>551</b>	2681	1879	2190	<b>2250</b>
<b>Mean</b>	<b>2028</b>	<b>1603</b>	<b>1654</b>		<b>826</b>	<b>483</b>	<b>503</b>		<b>2861</b>	<b>2080</b>	<b>2157</b>		<b>2762</b>	<b>1574</b>	<b>1710</b>		<b>830</b>	<b>456</b>	<b>665</b>		<b>3592</b>	<b>2030</b>	<b>2395</b>	
CD at 5%																								
S	162.88				103.37				164.73				96.97				187.73				155.32			
FL	214.01				168.15				159.94				152.70				75.73				177.17			
FL × S	NS				NS				296.45				272.42				159.76				323.28			
S × FL	NS				NS				298.89				258.87				219.92				317.75			

N<sub>1</sub>=control, N<sub>2</sub>=N<sub>100</sub>P<sub>50</sub>K<sub>25</sub>, N<sub>3</sub>=N<sub>150</sub>P<sub>75</sub>K<sub>37.5</sub>, N<sub>4</sub>=N<sub>200</sub>P<sub>100</sub>K<sub>50</sub>, N<sub>5</sub>=N<sub>250</sub>P<sub>75</sub>K<sub>62.5</sub>, N<sub>6</sub>=Biofertilizers, S<sub>1</sub>=60 cm × 60 cm, S<sub>2</sub>=70 cm × 30 cm, S<sub>3</sub>=80 cm × 30 cm

N×S= nutrient levels at same level of spacing, S×N= spacing at same level of nutrient levels

The above and below ground biomass was recorded higher in treatment N<sub>4</sub> (N<sub>200</sub>P<sub>100</sub>K<sub>50</sub>) and the lowest in control during both the years. Data reveals that maximum biomass (dry weight basis) of 3296 and 4281 (g) per plant was recorded in treatment (N<sub>200</sub>P<sub>100</sub>K<sub>50</sub>) and the lowest in control during both the years. Similar findings have been observed by Singh *et al.* 2019 in poplar nursery. They observed that the average maximum biomass (3.77 kg) per plant in poplar nursery was recorded with fertilizer application of N<sub>150</sub>P<sub>100</sub>K<sub>50</sub>. Total biomass of poplar plants increased significantly with successive increase in fertilizer doses during both the years of field studies which is comparable with the previous studies (Singh *et al.* 2001; Saravanakumar and Shanthinipriya, 2017 and Kumari *et al.* 2017).

## CONCLUSION

An experiment was conducted to determine the effect of nutrient levels and spacing on growth parameter and biomass production in poplar nursery. Nutrient application increased significantly the collar diameter, height, Leaf area, chlorophyll content and total biomass production. The highest growth in poplar was registered under the application of N<sub>200</sub> P<sub>100</sub> K<sub>50</sub> with 60×60 cm spacing. Wider spacing (60 × 60 cm) produced plants having significantly higher biomass production and growth parameter compared to other spacings of poplar.

## References

- Alcorn, P.J., Pyttel P., Bauhus J., Smith R.G.B., Thomas D., James R. and Nicotra A. 2007. Effects of initial planting density on branch development in 4-year-old plantation grown *Eucalyptus pilularis* and *Eucalyptus cloezianatrees*. *Forest Ecology and Management*. **252**(1–3): 41–51.
- Bilodeau-Gauthier, S. 2011. Shoot and root responses of hybrid poplars to interspecific competition and soil fertility. Dissertation, Université du Québec à Montréal.
- Bojović, B., and Stojanović, J. 2006. Some wheat leaf characteristics in dependence of fertilization. *Kragujevac Journal of Science*. **28**:139-146.
- Chauhan, S.K., Brar, M.S. and Sharma, R. 2012. Performance of poplar (*Populus deltoides* bartr.) and its effect on wheat yield under agroforestry system in irrigated agro-ecosystem, India. *Caspian Journal of Environmental Science*. **10**(1): 53-60.
- Chavan, S.B. and Dhillon, R.S. 2019. Doubling farmers' income through *Populus deltoides*-based agroforestry systems in northwestern India: an economic analysis. *Current Science*. **117**(2): 25.
- Damgaard, C., Strandberg, B., Mathiassen, S.K. and Kudsk, P. 2013. The Effect of Nitrogen and Glyphosate on Survival and Colonisation of Perennial Grass Species in an Agro-

- Ecosystem: Does the Relative Importance of Survival Decrease with Competitive Ability. *PLOS ONE*.**8**(4): e60992.
- DeBell DS, Clendenen GW, Harrington CA and Zasada JC 1996. Tree growth and stand development in short-rotation *Populus* plantings: 7-year results for two clones at three spacings. *Biomass Bioenergy*.**11**(4):253–269.
- den Driessche, R. 1999. First-year growth response of four *Populus trichocarpa* × *Populus deltoides* clones to fertilizer placement and level. *Canadian Journal of Forest Research*, **29** (5): 554-562.
- Deol, O.S. and Khosla, P.K. 1983. Provenance-related growth response of *Populus ciliate* Wall. ex. Royle to nitrogen fertilization. *Indian Forester*.**109**: 33-39.
- Dimitrov, Kh., Denev, D.A and Dimitrova, M 1976. Determining the optimum proportion of the main nutrient elements for *Populus X euraamericanacv*'I-214; *Gorskostopanska Nauka* **13**(4): 24-38.
- Dogra, A. S., Upadhyay, A., Sharma, S. C. and Chauhan, S.K. 2007. Potential of agroforestry as a land use option in Punjab, India. *Indian Forester*.**133**: 1437-1448.
- Durai, M.V., Ralhan, P.K., Sharma, R., Singh, A. and Chauhan, S. 2009. Nutrient harvest through pruned material and whole tree in *Populus deltoides* based agri-silviculture systems in Central Punjab. *Indian Forester*.**135**(12): 1716-1723.
- Faiz, M. and Singh, O. 2008. Influence of fertilizers and spacing on growth, litter production and soil fertility in poplar nursery. *Annals of Horticulture*.**1**(1): 49-53.
- Fang S, Xu X, Lu S and Tang L 1999. Growth dynamics and biomass production in short-rotation poplar plantations: 6-year results for three clones at four spacings. *Biomass Bioenergy*,**17**(5):415–425.
- Gangoo, S.A., Mughal, A.H. and Makaya, A.S. 1997. Fertilizer response by two species of poplar on initial growth parameters. *Indian Forester*.**123**: 240-244.
- Gola kiya, B. A. 1988. A system approach to resolve P × Zn antagonism in different soil water conditions. Ph.D. Thesis, Gujarat Agriculture University, Sardar Krushi Nagar.
- Handa, A.K., Sirohi, C., Chavan, S.B., Dhillon, R.S., Ahlawat, K.S. and Rizvi, R.H. 2020. Agroforestry in Haryana: Status and way forward. *Indian Journal of Agroforestry*.**22**(1): 1-10.
- Hegazy, S.S., Aref, I.M., Al-Mefarrej, H. and El-Juhany, L.I. 2008. Effect of spacing on the biomass production and allocation in *Conocarpus erectus* L. Trees grown in Riyadh, Saudi Arabia. *Saudi Journal of Biological Sciences*.**15**(2):315-322.

- ICFRE. 2016. Country report on poplars and willows period: 2012 to 2015. National Poplar Commission of India. Indian Council of Forestry Research and Education, Dehradun.
- Kerr G. 2003. Effects of spacing on the early growth of planted *Fraxinus excelsior* L. *Canadian Journal Forest Research*. **33**(7):1196–1207
- Khan, G.S. and Chaudhry, A.K. 2007. Effect of spacing and plant density on the growth of poplar (*Populus deltoides*) trees under agroforestry system. *Pakistan Journal of Agriculture Science*. **44**(2): 321-327.
- Kumari, S., Bhardwaj, K. K., Dhillon, R. S., and Singh, M. K. 2017. Effect of weed control methods and different fertilizer levels on growth characters of *Populus deltoides* Barts nursery. *Journal of Pharmacognosy and Phytochemistry*. **6**(5):2052-2056.
- Lal, P. 1993. Effect of nitrogen level, time of application and spacing on growth of seedlings of *Ulmus laevigata* Royal. M. Sc. Thesis. Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan (HP).
- Lanner R. M. 1985. On the insensitivity of height growth to spacing. *Forest Ecology Management*. **13**(3–4):143–148.
- Lei C Tao, ShaoLing W, GaiFang Z, ShuTian Y, Bing T, YongChun J and HuiLian MC, 2010. Effects of nitrogen fertilizer on fruit quality and leaf physiological metabolism of Hosui Pear. *Journal of Fruit Science*. **27**(6): 871 - 876.
- Mohan, S. 1992. Fertilizer response on the growth and biomass of a common timber species of Arunachal Pradesh *Terminalia myriocarpa* (Hollock) seedling. *Indian Forester*. **116**:822-831.
- Neto CB, Carranca C, Clemente J and Varennes A, 2011. Assessing the Nitrogen Nutritional Status of Young Non-Bearing ‘Rocha’ Pear Trees Grown in a Mediterranean Region by Using a Chlorophyll Meter. *Journal of Plant Nutrition*. **34**: 627 - 639.
- Nissen, T.M., Midmore, D.J. and Keeler, A.G. 2001. Biophysical and economic tradeoffs of intercropping timber with food crops in the Philippine uplands. *Agricultural Systems*, **67**:49-69.
- Odabas F, 1981. Effects to Chlorophyll Content of Nitrogen Fertilization on Bacchus Variety (*Vitis Vinifera* L.). *Atatürk University Journal of the Faculty of Agriculture*. **12** (2): 39-50.
- O’Rourke D, 2003.
- Pinkard E. A. and Neilsen W.A. 2003. Crown and stand characteristics of *Eucalyptus nitens* in response to initial spacing: implications for thinning. *Forest Ecology and Management* **172**(2–3): 215.

- Saravanakumar, R. and Shanthinipriya, A. 2017. Effect of inorganic fertilizers and growth performance in Poplar tree (*Populus deltoides*). *Research Journal of Agriculture and Forestry*. 5(9): 13-17.
- Sheddy, G. 1976. Research and development on poplar in eastern Quebec.VI-Green house fertilizer trials with N, P, K, Ca and Mg using various application methods. Min. Terres and For. Quebec, Canada 28 (15): 53pp.
- Sidhu, D. S. and Dhillon, G. P. S. 2007.Field performance of ten clones and two sizes of planting stock of *Populus deltoides* in Indo-gangetic plains of India.*New Forest*.34 (2): 115–122.
- Singh R.V. and Sharma K.C. 1984.Effect of nursery density on seedling characteristics of silver fir (*Abies pindrow* Spach.).*Indian Forester*.110 (11): 1078-1083.
- Singh, G., Singh, T. and Singh, A. 2019.Effect of fertilization on growth of poplar clones in nursery. *International Journal of Bio-resource and Stress Management*. 10 (1), 64-69.
- Singh, N.B., Kumar, D., Gupta, R.K. and Singh, K. 2001. All India coordinated research project on poplar improvement: need, implementation and achievement. *Advances in Horticulture and Forestry*.8: 205-237.
- Singh, S.K, Reddy, V.R. and Sicher, R.C. 2018.Seasonal critical concentration and relationships of leaf phosphorus and potassium status with biomass and yield traits of soybean.*Journal of Plant Nutrition and Soil Science*, 181:575–585.
- Sofi, P.A. 2005. Standardization of nursery technology of *Cedrus deodara*. Ph. D. Thesis. Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan, India, pp. 176.
- Sofi, P.A., Aslam M., Masoodi T.H., Pala N.A., Rashid M. and Peerzada I. 2020. Influence of seed source and stratification on germination and growth of *Betula utilis* D. Don under temperate conditions in Kashmir Himalaya. *Indian Forester*, 146 (6): 532-537
- Tajul, M. I., Alam, M. M., Hossain, S. M. M., Naher, K., Rafii, M. Y. and Latif, M. A. 2013. Influence of plant population and nitrogen-fertilizer at various levels on growth and growth efficiency of maize. *The Scientific World Journal*.2013: 1-9. <https://doi.org/10.1155/2013/193018>.
- Uysal E, Sağlam MT and Büyükyılmaz M, 2013.Effects to Chlorophyll Content of Fertigation and Foliar Nitrogen Application on Deveci Pear Variety. Soil-Water Journal Special Issue for AGRICASIA'2013 1st Central Asia Congress on Modern Agricultural Techniques and Plant Nutrition 1-3 October 2013, Bishkek, Kyrgyzstan, p. 67-74.
- Vidhya, C. 2012. Studies on effect of stand density on productivity and wood properties of Casuarina hybrid clone, M.Sc. thesis, Tamil Nadu Agricultural University, Coimbatore.

YanJun, Y., Jinhua, Z., Linjing, C., Aiqing, J., Hongmei, Z. and Pingyi, G. 2018. Effect of fertilizer levels and plant density on chlorophyll contents, its fluorescence and grain yield of *Setariaitlica*. *International Journal of Agriculture and Biology*.20 (4): 737-744.