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_1= N_0 P_0 K_0 (Control), N_2= N_{100} P_{50} K_{25}, N_3= N_{150} P_{75} $K_{37.5}$, N_4= N_{200} P_{100} K_{50}, N_5= N_{250} P_{75} $K_{62.5}$ and N_6= N_0 P_0 K_0 + 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 experimental 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. The performances of growth were influenced by N, P and K at different levels during 2019 and 2020 in poplar nursery were found significantly higher in $N_{200}P_{100}K_{50}$ and the lowest in control among all the other nutrients levels. 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_{200} P_{100} K_{50} 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 (Himshikha *et al*. 2020, Kumar *et. al.* 2022). 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; Poonia & Tripathi, 2015). 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 performance 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 Department of Forestry, CCS Haryana Agricultural University Hisar (Haryana) during 2019 and 2020. Geographically, the experimental site is situated at 29^{o} 09$^{'}$N latitude and 75^{o} 43$^{'}$E longitude at an elevation of 215.2 m above mean sea level situated in the semi-arid region of north-western India. The soil of the experimental site was sandy loam in texture, low in organic carbon and available nitrogen, medium in available phosphorus and high in available potassium. The initial soil samples were analyzed and found pH ranged from 8.02 to 8.15, EC 0.51-0.53 dSm^{-1}, OC- 0.40-0.43 %, available N 130-132.6 kg ha^{-1}, available P -13.60-14.30 kg ha^{-1} and available K 287 -289kg ha^{-1}

at surface layer in both the experimental years.

Data Collection

The present study were carried with six nutrient levels *viz*, (N_1= N_0 P_0 K_0 (Control), N_2= N_{100} P_{50} K_{25}, N_3= N_{150} P_{75} $K_{37.5}$, N_4= N_{200} P_{100} K_{50}, N_5= N_{250} P_{75} $K_{62.5}$ and N_6= N_0 P_0 K_0 + Biofertilizers) and three spacing (60×60 cm, 70×30 cm and 80×30 on growth of poplar clone (G-3) 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 (250ml Aldrex 30 E.C. 100 litre water) as an ant termite measure. Thereafter, the cuttings were 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 G-3 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 above and below ground biomass was calculated using destructive sampling method. Five plants were selected from each treatment i.e., spacing and nutrient level. Hence, 90 plants were selected for further harvesting to evaluate the effect of treatment on biomass production. The biomass of harvested trees was divided into two categories *i.e.,* aboveground biomass (stem, branch and leaf) and belowground biomass (roots). Each selected plant of *P.deltoides* was cut at ground level (leaving 10 cm of stump) and the crown (including branches and foliage) was removed from the stem. The aboveground biomass (AGB) was separated into stem biomass, branch biomass, and foliage biomass. The stem at the top was cut at 3 cm diameter and the part smaller than 3 cm was included in the branches portion. Foliage was removed from the branches by hand, and both were weighed fresh in the field using a digital weighing balance and the values were recorded. Subsamples of branches and foliage were labeled, bagged, and then transported to the laboratory of Department of Forestry, CCS HAU, Hisar (India). The subsamples were then dried at 70±2 °C to a constant weight for determination of water content. The dry weight for branches and foliage was then calculated. The stem was divided into different sections i.e., the base (ground to 1.3 m), middle (1.3 m to halfway from top), and top. Fresh weight was determined for each component and all samples were oven dried to a constant weight at 70±2 °C. Weights were recorded to calculate dry matter content (%) of samples and total dry biomass (kg tree^{-1}) as per given formulae.

$$\text{DMC (\%)} = \frac{ds1+ds2+ds3}{fs1+fs2+fs3} X100 \quad \text{...... \textbf{(Equation 1)}}$$

Where, DMC: Dry matter content (%); 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

To evaluate the below ground biomass (BGB) of plants, the root system were excavated of selected plants from the area of 1.0m around the tree stump. The sample plant roots were harvested to a depth of 100 cm by tractor mounted backhoe loader or spade/pickaxe to collect total belowground biomass and the root samples were weighed; air dried and kept in oven at 70±2 °C for 48–72 hours, immediately. The dry biomass of roots was calculated as per above mentioned formulae.

RESULTS AND DISCUSSION

Sprouting of cutting

The data depicted in Table 1 shows 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 98.45of 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^{-1}. Similarly, Damagaard *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_1 (60×60 cm)	S_2 (70×30 cm)	S_3 (80×30 cm)	Mean	S_1 (60×60 cm)	S_2 (70×30 cm)	S_3 (80×30 cm)	Mean
N_1= (Control)	82.53	86.71	92.68	87.31	84.86	84.76	95.11	88.24
N_2= $N_{100}\,P_{50}\,K_{25}$	95.76	84.35	90.28	90.13	95.83	84.29	87.78	89.30
N_3= $N_{150}\,P_{75}\,K_{37.5}$	98.40	95.97	81.91	92.09	98.45	96.33	83.22	92.67
N_4= $N_{200}\,P_{100}\,K_{50}$	89.05	90.29	92.21	90.52	88.06	90.95	90.67	89.89
N_5= $N_{250}\,P_{75}\,K_{62.5}$	95.03	85.38	94.76	91.73	91.11	88.57	94.67	91.45
N_6= Biofertilizers	88.31	91.12	86.53	88.65	87.64	92.86	84.33	88.28
Mean	**91.57**	**89.09**	**89.83**		**90.99**	**89.63**	**89.29**	
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 60×60 cm and 80×30 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_1 (60×60 cm) followed by 80×30 cm and 70×30 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 completion for moisture, sun light and nutrients in nursery. The highest dbh growth under 60×60 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 (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

Fertiliz	Plant height/sprout length (m) after plantation of cuttings at 3 months interval

er Levels	**2019**												**2020**											
	3 MAP				**6 MAP**				**9 MAP**				**3 MAP**				**6 MAP**				**9 MAP**			
	S_1	**S_2**	**S_3**	**Mean**	**S_1**	**S_2**	**S_3**	**Mean**	**S_1**	**S_2**	**S_3**	**Mean**	**S_1**	**S_2**	**S_3**	**Mean**	**S_1**	**S_2**	**S_3**	**Mean**	**S_1**	**S_2**	**S_3**	**Mean**
N_1	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_2	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_3	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_4	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_5	1.68	1.90	1.80	**1.79**	3.80	4.20	3.80	**3.93**	5.80	5.30	5.50	**5.53**	1.67	1.91	2.06	**1.88**	3.60	4.20	4.00	**3.93**	6.50	6.79	6.60	**6.63**
N_6	1.33	1.77	1.62	**1.57**	3.30	3.60	3.50	**3.47**	6.08	6.29	6.15	**6.17**	1.27	1.95	1.75	**1.66**	3.50	3.43	3.41	**3.45**	5.92	6.08	5.88	**5.96**
Mean	**1.47**	**1.81**	**1.72**		**3.51**	**3.96**	**3.53**		**5.00**	**6.10**	**5.40**		**1.55**	**1.99**	**1.85**		**3.62**	**3.86**	**3.65**		**6.04**	**6.53**	**6.20**	
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_1=control, N_2=$N_{100}P_{50}K_{25}$, N_3=$N_{150}P_{75}K_{37.5}$, N_4=$N_{200}P_{100}K_{50}$, N_5= $N_{250}P_{75}K_{62.5}$, N_6=Biofertilizers, S_1=60 cm × 60 cm, S_2= 70 cm × 30 cm, S_3= 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_4 (N_{200} P_{100} K_{50}) 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_{200} P_{100} K_{50} (N_4). However, the higher fertilizer level N_5 ($N_{250}P_{75}K_{62.5}$) showed inhibitory effect due to which plant height was observed lesser in N_5($N_{250}P_{75}K_{62.5}$) as compared to N_4 (N_{200} P_{100} K_{50}). 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_4 (N_{200} P_{100} K_{50}) 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_4 ($N_{200}P_{100}K_{50}$) 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_5 $N_{250}P_{75}K_{62.5}$ (N_5) 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 $N_{200}P_{100}K_{50}$ kg ha^{-1} 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_{250} P_{75} $K_{62.5}$ 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_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**
N_1	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_2	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_3	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_4	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_5	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_6	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**	
CD at 5%																								

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_1=control, $N_2=N_{100}P_{50}K_{25}$, $N_3=N_{150}P_{75}K_{37.5}$, $N_4=N_{200}P_{100}K_{50}$, $N_5= N_{250}P_{75}K_{62.5}$, N_6=Biofertilizers, S_1=60 cm × 60 cm, S_2= 70 cm × 30 cm, S_3= 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_2 (70×30 cm) while minimum was recorded in wider spacing S_1 (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_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**
N_1	34.60	35.23	33.50	**34.45**	50.90	50.70	51.93	**51.18**	38.80	37.00	38.70	**38.17**	35.70	33.33	37.40	**35.48**	50.12	54.56	50.00	**51.56**	40.80	38.00	39.00	**39.27**
N_2	38.10	38.60	39.20	**38.63**	51.80	54.30	52.40	**52.83**	41.70	42.80	41.80	**42.10**	37.30	39.60	38.10	**38.33**	54.39	56.90	53.10	**54.80**	42.66	41.70	43.21	**42.52**
N_3	39.90	39.70	40.40	**40.00**	57.60	57.60	54.80	**56.67**	43.90	44.80	43.60	**44.10**	38.30	42.83	40.04	**40.39**	55.90	57.00	56.00	**56.30**	43.44	49.54	43.30	**45.43**
N_4	41.70	44.60	43.81	**43.37**	59.10	62.12	63.45	**61.55**	47.80	50.80	49.50	**49.37**	41.80	46.72	42.67	**43.73**	64.10	60.10	63.70	**62.63**	48.72	49.00	47.90	**48.54**
N_5	40.60	43.30	40.56	**41.49**	57.70	60.50	59.13	**59.11**	45.80	45.90	46.40	**46.03**	38.40	44.16	45.12	**42.56**	58.00	56.90	58.44	**57.78**	45.78	47.23	48.00	**47.00**
N_6	33.10	37.88	38.98	**36.65**	48.60	52.90	52.20	**51.23**	41.10	40.60	40.30	**40.67**	34.60	38.14	37.67	**36.80**	49.24	53.90	52.00	**51.71**	41.50	39.10	42.80	**41.13**

Mean	**38.00**	**39.89**	**39.41**		**54.28**	**56.35**	**55.65**		**43.18**	**43.65**	**43.38**		**37.68**	**40.80**	**40.17**		**55.29**	**56.56**	**55.54**		**43.82**	**44.09**	**44.04**	
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_1=control, $N_2=N_{100}P_{50}K_{25}$, $N_3=N_{150}P_{75}K_{37.5}$, $N_4=N_{200}P_{100}K_{50}$, $N_5= N_{250}P_{75}K_{62.5}$, N_6=Biofertilizers, S_1=60 cm × 60 cm, S_2= 70 cm × 30 cm, S_3= 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 ($N_{250}P_{75}K_{62.5}$) followed by (N_{200} P_{100} K_{50}), (N_{150} P_{75} $K_{37.5}$), (N_{100} P_{50} K_{25}) 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_{220} kg ha^{1} 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_1 (60×60 cm) and minimum in S_2 (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

($N_{250}P_{75}K_{62.5}$) 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^2) was recorded in treatment ($N_{150}P_{100}K_{50}$). 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^2)of poplar cuttings at 3 months interval in nursery

Fertilizer levels	**leaf area (cm^2)after plantation of cuttings at 3 months interval**																							
	2019												**2020**											
	3 MAP				**6 MAP**				**9 MAP**				**3 MAP**				**6 MAP**				**9 MAP**			
	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**
N_1	118.35	119.40	137.44	**125.06**	318.41	280.41	296.56	**298.46**	295.37	266.81	277.45	**279.88**	130.41	120.00	128.24	**126.22**	314.17	292.19	301.26	**302.54**	296.37	274.32	295.37	**288.69**
N_2	146.32	130.00	166.48	**147.60**	322.53	305.14	309.42	**312.36**	301.78	285.06	288.82	**291.89**	158.07	150.02	153.60	**153.90**	319.58	311.98	313.38	**314.98**	300.68	282.40	288.09	**290.39**
N_3	153.66	150.00	183.97	**162.54**	328.53	310.02	318.55	**319.03**	306.29	283.35	294.91	**294.85**	158.49	154.49	155.23	**156.07**	328.65	312.98	317.76	**319.80**	308.29	282.45	286.94	**292.56**
N_4	168.26	180.38	209.34	**185.99**	329.93	323.70	326.47	**326.70**	310.13	301.34	305.61	**305.69**	185.47	180.55	181.37	**182.46**	330.96	320.46	326.03	**325.82**	312.19	292.71	306.95	**303.95**
N_5	183.59	170.44	191.69	**181.91**	339.29	334.13	334.46	**335.96**	318.63	306.67	306.78	**310.70**	199.00	172.27	188.11	**186.46**	343.94	327.36	335.10	**335.47**	321.21	299.42	312.28	**310.97**
N_6	133.51	128.57	173.30	**145.13**	321.29	291.28	301.59	**304.72**	294.57	273.94	279.35	**282.62**	146.76	134.57	136.47	**139.26**	318.66	291.78	297.94	**302.79**	291.97	279.63	290.30	**287.30**
Mean	**150.62**	**146.47**	**177.04**		**326.66**	**307.45**	**314.51**		**304.46**	**286.19**	**292.15**		**163.03**	**151.98**	**157.17**		**325.99**	**309.46**	**315.25**		**305.12**	**285.16**	**296.65**	
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_1=control, N_2=$N_{100}P_{50}K_{25}$, N_3=$N_{150}P_{75}K_{37.5}$, N_4=$N_{200}P_{100}K_{50}$, N_5= $N_{250}P_{75}K_{62.5}$, N_6=Biofertilizers, S_1=60 cm × 60 cm, S_2= 70 cm × 30 cm, S_3= 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_1 (60×60 cm) and minimum was in S_2 (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_1	1328	995	1008	**1110**	530	407	380	**439**	1859	1403	1388	**1550**	1722	1273	1200	**1398**	493	339	389	**407**	2215	1612	1589	**1806**
N_2	1853	1414	1550	**1606**	828	544	498	**623**	2682	1959	2048	**2230**	2028	1466	1607	**1701**	741	400	636	**592**	2770	1866	2244	**2293**
N_3	1925	1685	1723	**1778**	900	545	500	**648**	2826	2231	2223	**2427**	2186	1629	1927	**1914**	870	479	756	**702**	3056	2108	2683	**2616**
N_4	2945	2286	2276	**2502**	1100	650	597	**782**	4079	2937	2874	**3296**	5999	1976	2083	**3353**	1226	620	940	**929**	7226	2596	3023	**4281**
N_5	2265	1857	1858	**1993**	900	501	551	**651**	3166	2325	2410	**2633**	2614	1618	1851	**2028**	990	500	791	**761**	3604	2118	2642	**2788**
N_6	1,852	1380	1508	**1580**	700	248	492	**480**	2552	1629	2001	**2061**	2025	1482	1590	**1699**	656	398	600	**551**	2681	1879	2190	**2250**
Mean	**2028**	**1603**	**1654**		**826**	**483**	**503**		**2861**	**2080**	**2157**		**2762**	**1574**	**1710**		**830**	**456**	**685**		**3592**	**2030**	**2395**	
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_1=control, $N_2=N_{100}P_{50}K_{25}$, $N_3=N_{150}P_{75}K_{37.5}$, $N_4=N_{200}P_{100}K_{50}$, $N_5= N_{250}P_{75}K_{62.5}$, N_6=Biofertilizers, S_1=60 cm × 60 cm, S_2= 70 cm × 30 cm, S_3= 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_4 ($N_{200}P_{100}K_{50}$) 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 ($N_{200}P_{100}K_{50}$) 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 $N_{150}P_{100}K_{50}$. 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_{200} P_{100} K_{50} with 60×60 cm spacing. Wider spacing (60 × 60 cm) produced plants having significantly higher biomass production and growth parameter compared to other spacing's of poplar.

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