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EFFECT OF DIFFERENT SPACING'S OF POPLAR ON GROWTH, YIELD ATTRIBUTING TRAITS AND FODDER YIELD OF COWPEA UNDER SILVI-PASTORAL SYSTEM

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SUMMARY

A field experiment was conducted during 2018 to study the growth and production of fodder cowpea (var. RC-19) under different spacing's, i.e. 3 × 3 m, 4 × 3 m, 5 × 3 m, 6 × 3 m, 7 × 3 m and 8 × 3 m of two and half year old poplar-based agroforestry system. The maximum plant population (20.17/m^2) was recorded in 8×3 m spacing followed by 7×3 m, 6×3 m, 5x3 m, 4x3 m and least under 3×3 m at 15 DAS. A similar trend of plant height and leaf area index of cowpea was observed after 30, 45, 60 and 75 DAS as it follows the increasing trend with increase in spacing. Among the different spacing's of poplar, the fodder yield of cowpea was recorded maximum (8.95 t/ha) under 8×3 m followed by 7×3 m (7.24 t/ha), 6×3 m (6.06 t/ha), 5×3 m (4.45 t/ha), 4×3 m (2.99 t/ha) and minimum (2.20 t/ha) under 3×3 m spacing. All the growth and yield attributes of cowpea were recorded lesser under different spacing's of poplar as compared to the control (devoid of trees). The reduction in fodder yield under different spacing's 3 × 3 m, 4 × 3 m, 5 × 3 m, 6 × 3 m, 7 × 3 m, 8 × 3 m of poplar was 81.71, 75.14, 63.00, 49.62, 39.81 and 25.60 per cent, respectively over control (sole cowpea), demonstrating that the cowpea is susceptible to shade. While maximum (2.03) benefit to cost ratio was observed under poplar + cowpea combination in closer plant geometry of 3×3 m due to more number of trees.

Key words : Agroforestry, cowpea, poplar, spacing, fodder yield

Although agriculture is the backbone of the Indian economy, livestock is an important secondary enterprise in the country's crop husbandry. About 20.5 million peoples in the country rely upon livestock for their livelihood and this sector contributes 24.72 per cent to total agricultural gross domestic product (Hindoriya *et al*., 2019). According to the 20th livestock census, the total livestock population in the country is 535.78 million with an increase of 4.6 % over livestock census of 2012. Thus India assists 20 % of the livestock population of the world with 2.3 % of total geographical area. Year after year, the cattle population grows significantly, putting a strain on the country's available feed and fodder resources. Our country faced severe fodder shortage during lean period. The country has a net shortage of 61.1 % green fodder, 21.9 % dry agricultural leftovers, and 64 % concentrate feeds at the moment (Datta, 2013). India currently has only 5.4 % (8.4 million ha) of its cultivated land under forage crops, resulting in a severe fodder shortage.. India rank's first in milk production as well as cattle population thus production of better quality feed at cheap cost is crucial to improves farmers income (Kumari *et al*., 2017). According to Surve *et al.* (2011), the availability of good quality green fodder is critical to the success of livestock production, and without it, it is impossible to maintain animal health and milk productivity (Manoj and Shekara, 2020). Furthermore, because of the pressures of an ever-increasing population on food demand and nutritional security, there is no way to expand the area under fodder crops. In this context there is a need of strategies or practises that improves the productivity and quality of fodder crops per unit area and time with effective utilization of existing resources.

Adoption of agroforestry as a way of enhancing both the productivity and the quality of fodder. Agroforestry systems with trees or shrub alleys within fodder crops can be an option to reduce the fragility of certain agricultural production systems**.** Growing of fodder crops under poplar will not only meet the demand of fodder for animals but will also increase its availability during lean period. Therefore, there is a great need to identify the suitable fodder crops, which can grow well along with tree plantation with limited solar energy available underneath the trees (Ranjan *et al*., 2016).

Cowpea (*Vigna unguiculata*) commonly

known as Lobia in Hindi, is an important quick growing, leguminous and rainy season fodder crop, which is an integral part of traditional cropping systems in the semi-arid regions of the tropics. It has ability to tolerate drought and fix atmospheric nitrogen which allows it to grow and improve poor soils (Nguyen *et al*., 2019). It has emerged out as a potential crop for meeting the requirement of high quality protein fodder to fast expanding cattle population. Its green tender plants and leaves are used for feeding domestic animals as green fodder (Nguyen *et al*., 2016). It contains 20-24 per cent crude protein, 43-49 per cent neutral detergent fibre, 34-37 per cent acid detergent fibre, 23-25 percent cellulose and 5-6 per cent hemicelluloses on dry matter basis. The digestibility of cowpea fodder is above 70 per cent. Africa is considered as primary centre of origin. In India, cowpea grown in total area 407.93 lakh ha with a production 7925.25 lakh tones and productivity 19.47 tones/ha, respectively (Kumar *et al*., 2020). Cowpea is a drought tolerant crop can thrives best in different adverse climatic conditions and improves soil fertility (Vijayakumar *et al*., 2020). Therefore identification of best spacing of poplar to maximize the fodder yield of cowpea is important; so that it can contribute to fulfill the fodder demand. There is a large gap between the demand and supply of green fodder during the lean period. Thus, the goal of this study was to assess the productive yield of cowpea in single crop and mixtures in the poplar based agroforestry system under different spacing's.

MATERIALS AND METHODS

The present investigation was conducted at the Department of Forestry's research farm area at CCS Haryana Agricultural University, Hisar. during the year 2018. The experimental site is located in the semi-arid region of north-western India at 29o 09' N latitude and 75o 43' E longitude, at an altitude of 215.2 m above the mean sea level.. Hisar region mainly consists of plain land, 90% of its cultivated area is irrigated, either through crop cultivation or agroforestry systems, and irrigation is provided by high-quality canal or tube-well water. The climate is subtropical-monsoonic with an average annual rainfall of 350-400 mm, 70-80 per cent of which occurs during July to September. The present study was conducted in two and half-year-old plantation of *Populus deltoides* with six different spacing's of 3 × 3 m, 4 × 3 m, 5 × 3 m, 6 × 3 m, 7 × 3 m and 8 × 3 m. The mean height, basal diameter and diameter at breast height (DBH) of poplar saplings at the time of transplantation were 5.46 m, 3.51 cm and 2.83 cm, respectively. The experiment was laid out in factorial randomized block design with three replications.

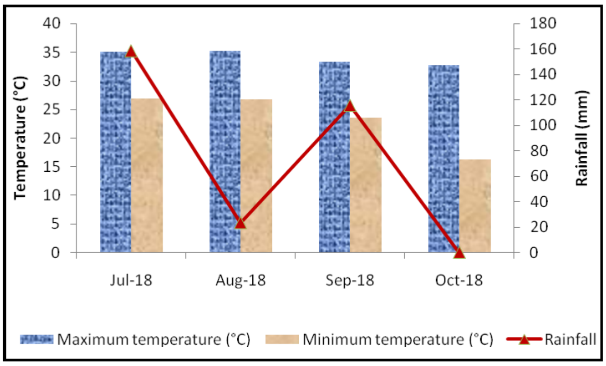

Fig. 1. The mean meteorological data of the study site during investigation.

During rainy season cowpea (var. RC-19) was sown in all spacing's of poplar under study during first week of July and also in control (without tree) with the recommended cultural practices during 2018. Data of fodder cowpea was recorded from different spacing's of poplar as well as from control. The plant population of cowpea was recorded 15 days after sowing (DAS) by counting number of plants per meter square under different spacing's of poplar. Plant height (cm), fresh weight per plant (g) and dry weight per plant (g) of cowpea was observed at 15 days interval. Fresh fodder yield (t ha^{-1}) and dry fodder yield (t ha^{-1}) were determined at harvest. Dry fodder yield was determined by first shade-drying followed by sun drying and then oven drying of harvested samples at 70°C till constant weight was attained. Leaf area was calculated at every 15 days interval with the help of a leaf area meter and then the leaf area index was calculated using the formula;

$$\text{Leaf area index} = \frac{\text{Leaf area}}{\text{Ground area}} \times 100$$

The land rent, cultivation costs, and gross income from various spacing's of poplar-based silvi-pastoral systems were computed using accepted market input and output prices. The total cost of cultivation and the total income generated from all the components were used for the determination of the net return, B:C ratio, internal rate of return (IRR) and net present worth (NPW). The above parameters were also recorded in control field and data were statistically analyzed.

RESULTS AND DISCUSSION

Plant population/m^2

The results depicted in Figure 2 show a significant variation in plant population of cowpea in the interspaces of different spacing's (3 × 3 m, 4 × 3 m, 5 × 3 m, 6 × 3 m, 7 × 3 m, 8 × 3 m) and sole crop (cowpea without trees). Among different spacing's of poplar, the highest number (37.26) of plant population of cowpea was recorded under control followed by 8×3 m (30.58), 7×3 m (27.48), 6×3 m (26.73), 5×3 m (24.43), 4×3 m (22.25) spacing's and least (20.17) under 3×3 m. The reduction in the plants population of cowpea under different spacing of poplar ranged from 17.92 % (8×3m) to 45.86% (3×3m) over control (sole cowpea). The plant population of cowpea was lesser under different spacing's of poplar as compared to the control (crop in open). This might be due to higher soil moisture content during July (rainy season) and lesser availability of solar radiation impedes the germination of cowpea under different spacing's of poplar. Similar findings have been published by Pal *et al.* (2009) in wheat under poplar based agroforestry system, Bargali *et al.* (2004) in chickpea under *Acacia nilotica* based agroforestry system. Kumar *et al.* (2013), Chauhan *et al.* (2015), Sharma *et al.* (1992), Kohli and Saini (2003), Datta and Singh (2007) and Gawali *et al.* (2015) also reported lesser plant population of crops under different spacing's of multipurpose tree species.

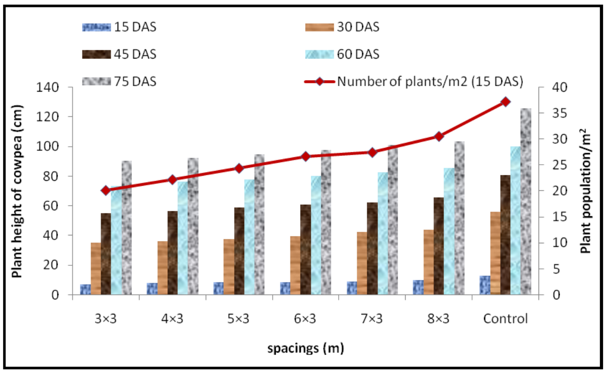

Fig. 2. Plant population and plant height of cowpea under different spacing's.

Plant height (cm)

Data presented in Figure 2 indicates the variation in plant height of cowpea under different plant geometry of poplar and also in comparison to control (sole crop) at different stages of growth (15, 30, 45, 60, and 75 DAS). It was observed that the maximum plant height (9.70 cm) of cowpea at 15 DAS was recorded in 8×3 m followed by 7×3 m (9.10 cm), 6×3 m (8.60 cm), 5×3 m (8.30 cm), 4×3 m (7.90 cm) and 3×3 m (7.20 cm) plant geometry. In control higher plant height of cowpea was recorded as 15 (13.00 cm), 30 (55.98 cm), 45 (80.56 cm), 60 (100.32 cm) and 75 DAS (125.70 cm). This might be due to the variation in the light intercepted by cowpea in open (crop devoid of trees) and under different spacing's of poplar. Cowpea is a legume crop and it requires more sunlight for biological nitrogen fixation as well as for photosynthesis. Under reduced light condition physiological processes slowed down and resulted in poor growth of the plants. The findings of present study supports the results of Kaur *et al.* (2010) and Sarvade *et al.* (2014). They reported significantly higher plant height of wheat in sole crop than the intercropping with poplar.

Yield attributes of cowpea

(a) Fresh weight/plant

The figures given in the Table 1 indicated that fresh weight per plant in cowpea was affected significantly under different spacing's of poplar in comparison to control (sole trees). The data showed that the higher fresh weight per plant (4.12 g) at 15 DAS was recorded under 8×3m followed by 7×3 m (4.06 g), 6×3 m (3.92 g), 5×3 m (3.89 g), 4×3 m (3.63 g) and 3×3 m (3.14 g) spacing's. A similar trend of higher fresh weight per plant was observed at 30, 45, 60 and 75 DAS under 8×3 m followed by 7×3 m, 6×3 m, 5×3 m, 4×3 m and 3×3 m spacing's whereas, highest fresh weight per plant at 15 (4.8 g), 30 (10.6 g), 45 (15.5 g), 60 (20.1 g) and 75 DAS (32.3 g) was recorded in control.

(b) Dry weight/plant

The data given in Table 1 shows that dry weight per plant in cowpea also differed significantly among different spacing's of poplar and control. The maximum dry weight per plant (2.06 g) at 15 DAS was recorded under 8×3m followed by 7×3 m (1.89 g), 6×3 m (1.86 g), 5×3 m (1.81 g), 4×3 m (1.72 g) and 3×3 m (1.59 g) spacing's. A similar trend of higher dry weight was observed at 30, 45, 60 and 75 DAS under 8×3m followed by 7×3 m, 6×3 m, 5×3 m, 4×3 m and 3×3 m spacing's whereas, maximum value of dry weight per plant at 15 (2.32 g), 30 (5.23 g), 45 (7.56 g), 60 (10.21 g) and 75DAS (16.01 g) was recorded in control (sole cowpea).

Leaf area index

In present investigation, it was observed that the leaf area index at different time intervals of growth (15, 30, 45, 60 and 75 DAS) of cowpea varied significantly under different spacing's of poplar (Figure 3). The results showed that the higher leaf area index (2.3) at 15 DAS was recorded under 8×3m followed by 7×3 m (2.1), 6×3 m (1.8), 5×3 m (1.7), 4×3 m (1.5) and 3×3 m (1.4) spacing's. A similar trend was observed at 30, 45, 60 and 75 DAS. At 30 DAS leaf area index ranged from 3.50 to 4.30, at 45 DAS (4.10 to 5.20), at 60 DAS (5.25 to 5.90) and at 75 DAS (4.80 to 6.00) under different spacing's of poplar. However, highest value of leaf area index was recorded in control (sole cowpea in open) at 15 DAS (3.1), 30 DAS (5.2), 45 DAS (5.8), 60 DAS (6.3) and 75 DAS (6.5). The decrease in leaf area index with decreasing spacing may be as a result of increased competition for light, nutrients, and moisture between tree and crop components. Thus, competition for utilization of growth resources adversely affected the leaf area index of cowpea under different spacing's of poplar. Kumar *et al.* (2014) revealed the similar results that leaf area index increased significantly with wider spacing and also with stage of growth.

Yield of cowpea

(a) Fresh Fodder yield (t/ha)

The results depicted in Figure 4 shows that a significant variation in fresh fodder yield of cowpea under different spacing's of poplar was recorded.

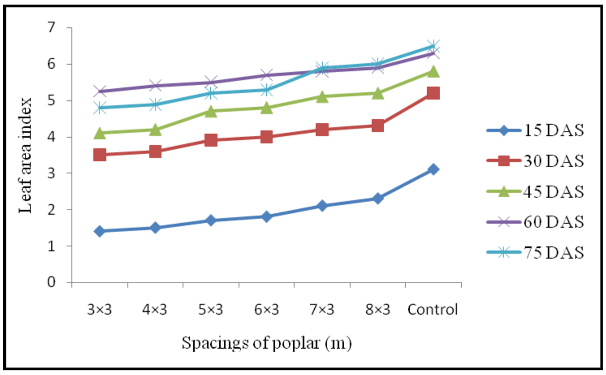

Fig. 3. Leaf area index of cowpea under different spacing's of poplar.

Among different spacing's of poplar, the maximum fodder yield (8.95 t/ha) of cowpea was recorded under 8 × 3 m followed by 7 × 3 m (7.24 t/ha), 6 × 3 m (6.06 t/ha), 5 × 3 m (4.45 t/ha), 4 × 3 m (2.99 t/ha) spacing's and the minimum (2.20 t/ha) under 3×3 m spacing. However, performance of cowpea in control (12.03 t/ha) was higher than different spacing's of poplar. The reduction in fodder yield of cowpea under spacing's 3 × 3 m, 4 × 3 m, 5 × 3 m, 6 × 3 m, 7 × 3 m, 8 × 3 m of poplar was 81.71, 75.14, 63.00, 49.62, 39.81 and 25.60 per cent, respectively over control (devoid of trees), revealing that cowpea is more shade-sensitive. The lesser availability of solar radiation and higher competition for growth resources in the silvi-pastoral system (poplar + cowpea) may be responsible for lesser biomass production by cowpea over control (devoid of trees).

Thus, competition for utilization of growth resources adversely affected the fresh fodder yield of cowpea under different spacing's of poplar. Bhati *et al.* 2004 revealed the similar result of fodder yield of cowpea and other fodder crops under the canopy of different agroforestry trees of arid regions of Rajasthan. Ranjan *et al.* (2016), Ratan *et al.* (2015), Prasad *et al.* (2010), Chesney *et al.* (2010) also

TABLE 1

Fresh weight and dry weight of cowpea under different spacing's of poplar

Tree spacing (m)	Fresh weight/plant (g)					Dry weight/plant (g)				
	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS
3×3	3.14	4.01	6.32	9.2	10.95	1.59	1.99	3.06	4.53	5.26
4×3	3.63	4.36	7.56	10.96	13.46	1.72	2.15	3.39	5.62	6.52
5×3	3.89	5.11	8.25	12.54	18.22	1.81	2.46	4.21	6.58	8.45
6×3	3.92	6.29	10.7	14.34	22.69	1.86	3.02	5.12	7.23	10.86
7×3	4.06	7.63	12.96	17.86	26.35	1.89	3.64	6.35	8.19	13.11
8×3	4.12	8.96	14.12	19.02	29.3	2.06	4.25	7.07	9.22	14.88
Control	4.8	10.6	15.5	20.1	32.3	2.32	5.23	7.56	10.21	16.01
CD at 5%	0.38	0.67	1.07	1.46	2.2	0.18	0.32	0.52	0.72	1.08

reported the corroborative results showing the reduction in grain yield of cowpea due to higher shade under *Eucalyptus tereticornis* based agroforestry system over open condition.

(b) Dry matter yield (t/ha)

The dry matter yield of cowpea also varied significantly under different spacing's of poplar and control (Figure 4). The yield of dry matter ranged from 1.06 to 4.55 t/ha and the highest dry matter yield (4.55 t/ha) of cowpea among the different spacing's of poplar under study was under 8×3 m followed by 7×3 m (3.60 t/ha), 6×3 m (2.90 t/ha), 5×3 m (2.06 t/ha), 4×3 m (1.45 t/ha) spacing's and the minimum under 3×3 m (1.06 t/ha) spacing. The dry matter yield of cowpea in control (5.96 t/ha) was higher than different spacing's of poplar. The reduction in dry matter yield of cowpea under spacing's 3 × 3 m, 4 × 3 m, 5 × 3 m, 6 × 3 m, 7 × 3 m, 8 × 3 m of poplar was 82.21, 75.67, 65.43, 51.34, 39.59 and 23.65 per cent, respectively over control (devoid of trees).

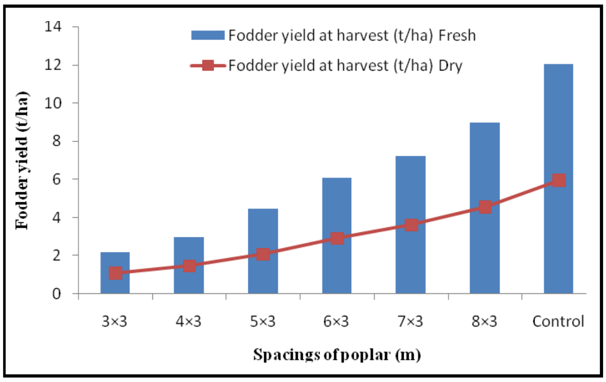

Fig. 4. Fodder yield (fresh and dry) of cowpea under different spacing's of poplar.

The reduced dry matter yield of fodder crops under poplar plantation may be ascribed to competition between tree and cowpea for light, moisture and nutrients in a poplar based agroforestry system. In intercropping system, competition for light has been reported to have a large influence than either moisture or nutrients and dry mater production bears an almost linear relationship with the quantum of intercepted energy (Monteith, 1977). More light intensity in control increased the photosynthetic efficiency of crops resulting in better growth as reported by Wassinck (1954). Light and nutrient availability are the primary factors affecting crop development. Similar results were earlier reported by Kaushik and Kumar (2003), Chesney *et al.* (2010) and Prasad *et al.* (2010) in different agroforestry systems. According to Sharma *et al.* (2000), close spacing of poplar trees inhibits wheat crop growth. Similar results were found by Alebachew *et al.* (2015). They reported that poor performance of maize sown adjacent to eucalypts plantation was due to competition for growth resources between eucalypts and adjacent crops. Results of the present investigation support the findings of Osman *et al.* (1998), Bhati *et al.* (2004), Datta and Singh (2007) and Bargali *et al.* (2009).

Economics of cowpea under different spacing's of poplar in silvi-pastoral systems

It is evidenced from the data presented in Table 2 that the total cost of cultivation was higher under closer plant geometry of 3×3 m in combination of poplar+ cowpea (Rs. 107712) and decreased with the increase in plant geometry of poplar. The maximum gross return was obtained from poplar + cowpea (Rs. 218611) under 3×3 m due to more number of trees in this spacing closely followed by 4×3 m (Rs. 168203). However, the gross return decreased with the increase in the spacing of poplar; however the minimum gross return was obtained under sole cropping of cowpea, *i.e.*, Rs. 39690. The maximum net return (Rs. 110899) was obtained under poplar + cowpea under 3×3 m spacing, while the minimum net return was obtained under sole cropping of cowpea, *i.e.*, Rs. 2764. In present study, it was observed that poplar + cowpea combination in closer plant geometry of 3×3 m resulted into maximum (2.03) benefit to cost ratio closely followed by 4×3 m (1.61) spacing. However, the minimum (1.07) benefit to cost ratio was obtained under 8×3 m spacing of poplar + cowpea combination (Table 2 and Fig. 5).

TABLE 2
Economics of cowpea with poplar and control (sole fodder crops)

Spacing (m)	Cost of cultivation (Rs./ha)	Gross return (Rs./ha)	Net return (Rs./ha)	B : C ratio
3×3	107712	218611	110899	2.03
4×3	104442	168203	63761	1.61
5×3	102480	140617	38136	1.37
6×3	101172	124336	23163	1.23
7×3	100861	112826	11965	1.12
8×3	99537	106647	7109	1.07
Control	36926	39690	2764	1.08

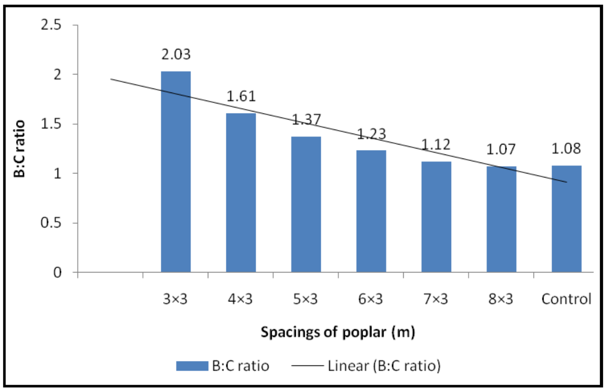

Fig. 5. Benefit Cost Ratio (B:C) of cowpea with poplar and control (sole cowpea).

CONCLUSION

It is concluded that production of cowpea was significantly lower in combination with all the six spatial arrangements of poplar when compared to control. Wider spacing (8×3 m) of poplar was found best for production of fodder cowpea, followed by 7×3 m and 6×3 m. Among the different spacing's of poplar, the fodder yield of cowpea was recorded maximum (8.95 t/ha) under 8×3 m followed by 7×3 m (7.24 t/ha), 6×3 m (6.06 t/ha), 5×3 m (4.45 t/ha), 4×3 m (2.99 t/ha) and minimum (2.20t/ha) under 3×3 m spacing. The reduction in fodder yield of cowpea under spacing's 3 × 3 m, 4 × 3 m, 5 × 3 m, 6 × 3 m, 7 × 3 m, 8 × 3 m of poplar was 81.71, 75.14, 63.00, 49.62, 39.81 and 25.60 per cent, respectively over control (sole cowpea), indicating that cowpea is more sensitive to shade. While maximum (2.03) benefit to cost ratio was observed under poplar + cowpea combination in closer plant geometry of 3×3 m. Thus, study concludes that 8×3 m spacing of poplar appears to be the best for intercropping cowpea with poplar based agroforestry system.

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