EFFECTS OF *POPULUS DELTOIDES* LITTER ON ITS SAPLINGS, ASSOCIATED AGRICULTURAL CROPS AND THE PROPERTIES OF AN ALKALI SOIL

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Received July 1995

SINGH, G., SINGH, H. & SINGH, J. 1997. Effects of *Populus deltoides* litter on its saplings, associated agricultural crops and the properties of an alkali soil. To study litter effects of poplar (*Populus deltoides*) on its saplings, associated agricultural crops and on the properties of an alkali soil, a pot study was conducted during 1994 using an alkali soil of pH 9.5 at the Central Soil Salinity Research Institute, Karnal, India. Twelve treatment combinations consisted of three litter levels (0, 1:4 and 1:2; litter to soil on volume basis) and four intercrop treatments [no crop, turmeric (*Curcuma longa*), guinea grass (*Panicum maximum*) and cowpea (*Vigna unquiculata*)] Each treatment was replicated three times in a completely randomised block design. The mean height increment and girth growth of the poplar recorded four months after planting were markedly better in litter-treated soil than in the case of no litter treatment. Similarly, leaf, stem and root biomass values of the poplar were also significantly more when it was planted in litter-mixed alkali soil than in no litter treatment. Further, growth and biomass were also greater when litter was added in 1:2 ratio than in 1:4 ratio. Poplar growth was significantly inferior when its saplings were grown with guinea grass as compared to the no intercrop treatment. Guinea grass yielded nearly 20% more fodder when litter was mixed in 1:2 ratio than in no litter treatment. Litter levels had little effect on P and K concentrations in poplar parts, whereas Na concentration in leaf, stem and root was highest in the no litter treatment. Application of litter caused appreciable reductions in pH and EC and improvements in organic carbon content of the alkali soil. On the other hand, available P and K status of the soil remained unaffected by the litter. The study suggests that addition of poplar litter to alkali soils may be a useful practice when productivity, reclamation and soil fertility aspects are considered.

Key words : Poplar litter - poplar saplings - associated crops - alkali soil - nutrient composition - soil properties

SINGH, G., SINGH, H. & SINGH, J. 1997. Kesan sarap *Populus deltoides* ke atas anak pokok, tanaman pertanian yang berkaitan dan ciri tanah beralkali. Untuk mengkaji kesan sarap poplar (*Populus deltoides*) ke atas anak pokoknya, tanaman pertanian yang berkaitan dan ciri tanah alkali, kajian boleh guna dijalankan pada tahun 1994 menggunakan tanah alkali pH 9.5 di Institut Penyelidikan Kemasinan Tanah Tengah, Karnal, India. Gabungan dua belas rawatan mengandungi tiga tahap sarap (0, 1:4 dan 1:2; sarap kepada tanah berdasarkan isi padu) dan empat rawatan tanaman selang [tiada tanaman, kunyit, (*Curcuma longa*), rumput guinea (*Panicum maxicum*) dan kacang duduk (*Vigna unquiculata*)]. Setiap rawatan diulangi tiga kali dalam bentuk blok rambang sepenuhnya. Pertambahan tinggi dan pertumbuhan lilit poplar yang dicatat empat bulan selepas penanaman lebih baik dalam tanah yang dirawat dengan sarap daripada yang tidak dirawat. Begitu juga biojisim daun, biojisim batang dan biojisim akar poplar juga ketara lebih tinggi apabila poplar ditanam di tanah alkali bercampur sarap alkali daripada tanah tanpa sarap. Tambahan pula, pertumbuhan dan biojisim juga lebih besar apabila sarap ditambah dalam nisbah 1:2 daripada dalam nisbah 1:4. Pertumbuhan poplar juga ketara lebih inferior apabila anak pokok ditanam dengan rumput guinea berbanding dengan tiadanya rawatan tanaman selang. Rumput guinea menghasilkan hampir 20% lebih foder apabila sarap dicampur dalam nisbah 1:2 daripada tiada rawatan. Tahap sarap mempunyai kesan yang sedikit ke atas kepekatan P dan K dalam bahagian poplar, di mana kepekatan Na dalam daun, batang dan akar tinggi dalam rawatan tanpa sarap. Penggunaan sarap menyebabkan pengurangan dalam pH dan EC dan peningkatan dalam kandungan karbon organik dalam tanah alkali. Sebaliknya status P dan K tanah yang boleh didapati kekal tidak dipengaruhi oleh sarap. Kajian mencadangkan tambahan sarap poplar kepada tanah alkali mungkin merupakan amalan yang berguna apabila aspek-aspek produktiviti, pemuliharaan tanah dan kesuburan tanah dipertimbangkan.

Introduction

India has a total land area of about 329 million ha, of which 93.6 million ha are wasteland producing only 20 per cent of its agricultural potential. Of this, 8.11 million ha (Singh 1992) suffer from excess of salts. The alkali soils alone reduce the productivity of 3.0 million ha in the Indogangetic alluvial plains. These soils are characterised by high exchangeable sodium, varying degree of calcareousness and excessively low permeability. A sizeable area under alkali soils has been reclaimed and is producing good crops of rice and wheat. However, a large chunk of alkali lands is in the possession of village panchayats (village judicial bodies). Owing to common property rights, there are several problems associated with the reclamation of such lands for crop production. Agroforestry is considered an option of great promise for use of such lands, particularly in view of the growing demand for fuel wood, timber, and fodder and also environmental considerations (Kaul & Mann 1977, Yadav 1980, Singh *et al.* 1993).

Trees of the genus *Populus* have promise for agroforestry owing to their fast growth, assured market, excellent wood quality, farmer's acceptability and less competition with agricultural crops when planted together in an agroforestry system. Further, being deciduous it sheds leaves completely during winter and thus minimises shading effect on intercrops. Poplar also adds sufficient litter to the soil through annual leaf fall which enhances the soil fertility. However, little is known about the litter effects of this multipurpose tree on its saplings during establishment stage, or effects on agricultural crops and on the properties of an alkali soil. The present study was, therefore, initiated to find answers to some of these practical problems.

Materials and methods

This study was conducted in 1994 in the pot house of the Central Soil Salinity Research Institute, Karnal (29° 43' N, 76° 58' E; 245 m a.s.l.). The climate is semi-arid with evaporation exceeding total rainfall in most of the months. An alkali soil of original pH 9.5 imported from the Gudha experimental farm of the institute was used for this study. Litter fallen on the ground under 5-y-old *Populus* *deltoides* trees planted in the field was collected and mixed in the alkali soil by volume in the ratio of 1:4 and 1:2 (litter : soil) before filling the 20 kg capacity ceramic pots. In the case of the 1: 4 treatment approximately 500 g air dried litter/pot was applied. Similarly, for the 1:2 treatment about 1 kg litter was added. The litter weighed 0.07 g cm^{-3}.

Twelve treatment combinations comprising three litter levels (0,1:4 and 1:2) and four intercrop treatments [no crop, turmeric (*Curcuma lonqa*), guinea grass (*Panicum maximum*) and cowpea (*Viqna unquiculata*)] were replicated three times in a completely randomised block design. After filling the soil in the pots, water was applied uniformly so that the soil was properly settled. Nearly three months old robust poplar saplings were planted on August 4 in the center of each pot. Irrigation was applied when necessary. No fertilisers were used. Intercrops of turmeric, guinea grass and cowpea were grown on August 6 using six rhizomes, eight seedlings and eight seeds respectively.

The poplar litter used for this study contained 1.38, 0.15, 0.68, 3.75, 1.25, 0.19 and 0.22 per cent of N, P, K, Ca, Mg, S and Na respectively. It also contained 3892, 34 and 366 ppm of Fe, Zn and Mn respectively.

Growth observations on both poplar saplings and on the agricultural crops were taken periodically. Poplar saplings were harvested on 22 November 1994 and their leaf, stem and root biomass was recorded.

Soil samples were taken in the middle of each pot before termination of the experiment to assess litter effects on soil properties. After collection, samples were air- and then oven-dried, ground in a wooden pestle and mortar, passed through a 2 mm sieve and analysed for pH, EC, organic carbon, available P and K contents following standard methods (Jackson 1967). Similarly, stem, leaf and root samples of poplar were analysed separately for chemical composition. Samples were washed with ordinary water, dilute acid (0.1% HCL), and single and double distilled water, then air -dried and oven- dried at 70 °C for 48 h, ground in a Wiley mill, passed through a 16-mesh sieve and stored in polyethylene bags. Samples of 1g were digested in a di-acid mixture (HNO_3:$HClO_4$, 3:1). The filtrate was preserved in 100-ml plastic bottles. These samples were analysed following standard procedures as outlined by Jackson (1967). The statistical analysis was done using ANOVA.

Results and discussion

Growth parameters

Average increments in height and girth growth of poplar as influenced by different litter levels in a growth period of four months are depicted in Figure 1. There were significant increase in height and girth growth of poplar with increase in the litter levels. This was probably due to the increased fertility status of the soil owing to litter addition. The guinea grass intercrop affected the height and girth of poplar adversely at all the litter levels. Guinea grass grew much taller than the poplar saplings thus smothering its saplings. Owing to the high alkalinity of the pot soil (pH 9.5), the performance of cowpea and turmeric was not satisfactory; therefore, litter effects on these intercrops could not be studied.

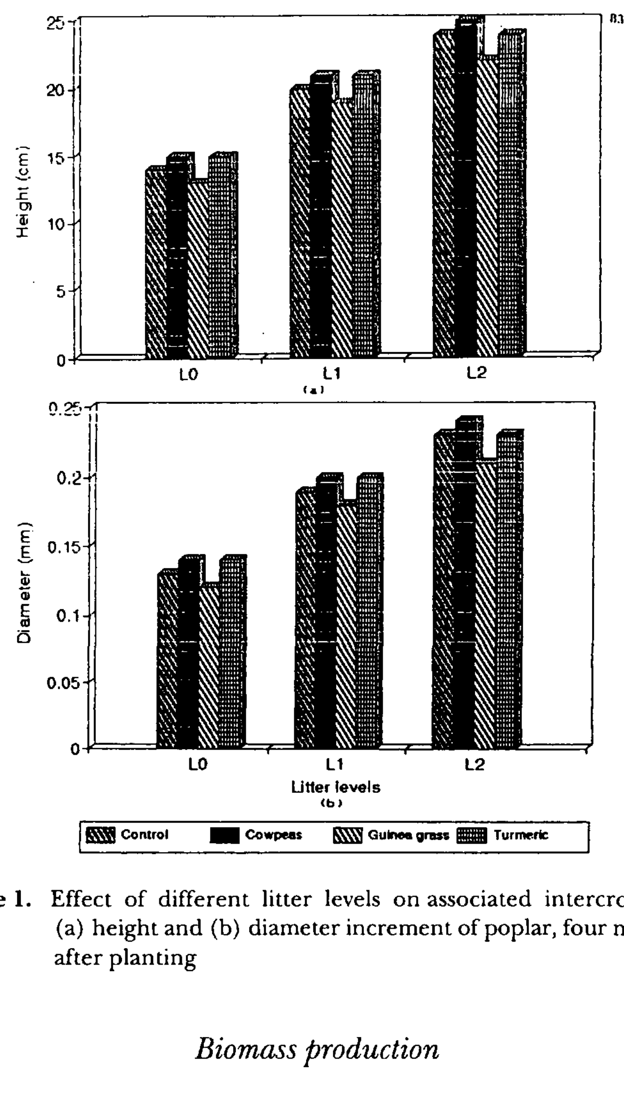

Figure 1. Effect of different litter levels on associated intercrops on (a) height and (b) diameter increment of poplar, four months after planting

Biomass production

Biomass accumulated in four months in different tree parts was in the order: root > stem > leaf. Biomass was significantly less when poplar was grown with guinea grass intercrop as compared to the treatments when it was grown either without intercrops or with cowpeas or with turmeric (Table 1). In all tree parts, there was a significant increase in the biomass with increase in each level of litter applied. The leaf, stem and root biomass values were almost double when litter was added in the ratio of 1:2 (litter:soil) compared to no litter treatment. As described below the biomass response in the litter treated soil probably can be ascribed to improvement in fertility status of the soil. There was no significant effect of litter levels on root-to-shoot ratio of poplar.

Table 1. Increase in leaf, stem and root biomass (g $plant^{-1}$) of poplar (P) as affected by various litter levels and intercrop treatments

	Leaf				Stem				Root			
	L0	L1	L2	Mean	L0	L1	L2	Mean	L0	L1	L2	Mean
P0	2.4	3.7	5.4	3.8	4.3	5.7	7.7	5.9	8.2	13.3	15.6	12.4
PC	2.5	3.8	5.5	3.9	4.4	5.8	7.9	6.0	8.3	13.3	15.7	12.4
PG	2.3	3.6	5.3	3.7	4.2	5.5	7.6	5.8	8.0	13.1	15.4	12.2
PT	2.5	3.8	5.5	3.9	4.4	5.8	7.9	6.0	8.3	13.2	15.6	12.4
Mean	2.4	3.7	5.4	-	4.3	5.7	7.8	-	8.2	13.2	15.6	-

CD ($p < 0.05$) for:

		Leaf	Stem	Root
crop (C)	=	0.14	0.17	0.12
litter (L)	=	0.12	0.14	0.11
C × L	=	ns	ns	ns

L0 : no litter
L1 : 1 : 4 litter : soil
L2 : 1 : 2 litter : soil

P0 : sole poplar
PC : poplar + cowpeas
PG : poplar + guinea grass
PT : poplar + turmeric

Performance of intercrops

Cowpea germination after 10 days was slightly higher in the litter-treated soil than in no litter treatment (Table 2). However, turmeric germination was little affected by the litter treatments. The mean height attained by the cowpea and turmeric in a growth period of 30 days was also higher in the litter-treated soil compared to the no litter treatment. Similarly, the height attained by the guinea grass in the same period was higher by 5 and 6 cm when litter was mixed in 1:4 and 1:2 ratios respectively, as compared to the no litter treatment. Green forage yield of the guinea grass was also significantly higher when litter was added in 1:2 ratio than when either no litter was added or when it was added in 1:4 ratio. This showed no antagonistic effect of poplar litter on the associated agricultural crops.

Nutrient concentrations

Macro-nutrients

The concentrations of P, K, Na, Ca and Mg in leaf, stem and root of poplar plants as influenced by litter levels and associated intercrops are given in Table 3. The concentrations of almost all the nutrients in the poplar parts were in the order: leaf > root > stem. This trend is commonly found in nutrient analysis of young woody plants (Steward *et al.* 1981, Singh 1982). There was no marked effect of litter levels on P and K concentrations in the poplar parts. However, the concentrations of these two nutrients in leaf, stem and root were comparatively less when poplar was grown with guinea grass. The Na concentration in the leaf was highest in the no litter treatment and was lowest when litter was added in 1: 2 ratio. A similar trend in Na accumulation was observed in the case of stem and root segments. The Mg concentrations in the leaf, stem and root were little affected by litter levels. Ca concentration in the leaf was higher when no litter was added than when litter

Table 2. Effect of litter levels on germination count and height of different crops planted with poplar

Crop	L0 Germination count/pot	L0 Height (cm) after days 30	L0 Height (cm) after days 90	L0 Yield g/pot	L1 Germination count/pot	L1 Height (cm) after days 30	L1 Height (cm) after days 90	L1 Yield g/pot	L2 Germination count/pot	L2 Height (cm) after days 30	L2 Height (cm) after days 90	L2 Yield g/pot
Cowpea	5	13	-	-	6	14	-	-	6	15	-	
Guinea grass	6	20	77	19	6	25	80	21	6	26	88	25
Turmeric	4	12	-	-	4	13	-	-	4	15	-	

Table 3. Effect of various treatments on concentration (%) of macro-nutrients in poplar

Treatment	Leaf P	Leaf K	Leaf Na	Leaf Ca	Leaf Mg	Stem P	Stem K	Stem Na	Stem Ca	Stem Mg	Root P	Root K	Root Na	Root Ca	Root Mg
PL00	0.13	1.50	0.98	1.40	0.38	0.10	0.77	0.44	0.75	0.33	0.17	0.87	0.68	0.80	0.32
PL0C	0.13	1.70	0.72	1.40	0.37	0.10	0.78	0.28	0.74	0.31	0.14	0.96	0.64	0.92	0.34
PL0G	0.12	1.50	1.10	1.50	0.37	0.09	0.85	0.28	0.82	0.30	0.10	0.87	0.60	1.00	0.34
PL0T	0.13	1.50	0.94	1.30	0.38	0.10	0.67	0.22	0.58	0.29	0.13	0.88	0.64	0.96	0.36
PL10	0.13	1.60	0.64	0.83	0.36	0.10	0.77	0.30	1.20	0.39	0.13	0.90	0.52	0.75	0.33
PL1C	0.13	1.80	0.68	0.94	0.36	0.09	0.73	0.22	1.30	0.40	0.12	1.10	0.52	0.59	0.32
PL1G	0.14	1.80	0.46	0.77	0.35	0.10	0.98	0.20	1.20	0.40	0.10	0.92	0.44	0.90	0.35
PL1T	0.13	1.70	0.54	0.91	0.36	0.10	0.67	0.20	1.40	0.40	0.13	1.00	0.54	0.60	0.32
PL20	0.14	1.70	0.42	1.30	0.39	0.12	0.96	0.22	0.89	0.34	0.14	1.00	0.26	0.86	0.36
PL2C	0.15	1.60	0.42	1.30	0.40	0.12	0.78	0.18	0.78	0.34	0.14	0.94	0.22	0.85	0.36
PL2G	0.11	1.70	0.42	1.10	0.39	0.08	0.85	0.16	0.61	0.31	0.10	0.96	0.22	0.77	0.34
PL2T	0.14	1.60	0.42	0.75	0.34	0.10	0.75	0.20	1.40	0.41	0.14	1.10	0.16	0.82	0.35

L0, L1, L2 = litter levels;
O : no crop, C : cowpea, G : guinea grass, T : turmeric.

Journal of Tropical Forest Science 9(4): 536 - 545 (1997)

was added. There was no particular trend with respect to intercrops effects on nutrient composition in different plant parts. The physiological explanations for this trend of nutrient concentration are beyond the scope of this study. To better understand the physiology of nutrient uptake further studies are suggested using a wider range of litter levels with more controlled environments.

Micro-nutrients

Zn concentration in the poplar increased with increase in levels of litter added to the soil (Table 4). Mean Zn concentration recorded after harvest of the poplar was 21 ppm when no litter was applied, 32 ppm when litter was applied in 1:4 ratio and 39 ppm in the case of 1:2 litter:soil ratio. Further, when no litter was added, Zn concentration was lowest when the poplar was grown without intercrops. Fe concentration in poplar was also higher when it was planted in litter-treated soil than in no litter soil. Irrespective of the litter levels and intercrop treatments, Fe concentration in the whole plant was highest when the poplar was grown with turmeric. Mn concentration was little affected by litter levels. Similar to Fe, Mn concentration in the poplar was also higher when it was planted with turmeric.

Table 4. Effect of various treatments on concentrations of micro-nutrients in poplar

Treatment	Zn	Fe	Mn	Mean
		ppm		
PL00	18	590	45.8	218
PL0C	22	562	48.4	211
PL0G	20	733	52.1	268
PL0T	23	1034	66.3	281
Mean	**21**	**730**	**53.2**	-
PL10	32	676	63.8	257
PL1C	27	908	47.4	327
PL1G	40	742	56.5	280
PL1T	29	1056	60.1	382
Mean	**32**	**846**	**57.0**	-
PL20	52	963	51.2	355
PL2C	41	670	43.3	251
PL2G	31	773	37.7	280
PL2T	33	822	67.6	308
Mean	**39**	**807**	**50.0**	-

Effect on soil properties

pH and EC

Application of poplar litter to the alkali soil resulted in a marked decrease in pH and EC of the soil (Table 5). The pH and EC values recorded four months after planting were respectively 9.35 and 1.1 dS m^{-1} in the no litter treatment, 9.30 and 0.8 dS m^{-1} when litter was mixed in 1:4 ratio, and 9.0 and 0.7 dS m^{-1} when litter was added in 1:2 ratio. The decrease in pH and EC of the soil by the addition of leaf litter was probably due to a decrease in exchangeable Na percentage of the soil. The effect of associated intercrops on pH and EC was not found significant.

Table 5. pH and EC (dS m^{-1}) of the pot soil as affected by various litter levels and intercrop treatments

Treatment	Litter levels							
	L0		L1		L2		Mean	
	pH	EC	pH	EC	pH	EC	pH	EC
P0	9.30	1.2	9.30	0.9	8.95	0.6	9.20	0.92
PC	9.32	1.1	9.30	0.7	9.00	0.6	9.20	0.81
PG	9.33	1.1	9.31	0.7	9.00	0.7	9.20	0.84
PT	9.41	1.0	9.23	0.7	9.10	0.8	9.20	0.82
Mean	9.35	1.1	9.30	0.8	9.00	0.7	-	-

CD ($p < 0.05$) for:		pH	EC
crops (C)	=	ns	ns
litter (L)	=	0.08	0.08
C × L	=	ns	ns

Organic carbon

As expected, mixing of poplar litter in the soil before planting the poplar saplings resulted in appreciable increase in the OC content of the soil (Table 6). This result is ascribed directly to the addition of the high C content litter and would be maintained for sometime because of delayed oxidation of recalcitrant organic compounds. The effects of associated intercrops on OC build-up were non-significant.

Available P and K

The phosphorus content of soil was little affected by litter addition (Table 6). The P status of the soil was highest where poplar was grown without any intercrop. Available K content of the soil recorded after the study period was less in the litter-treated soil than the treatment with no litter. Probably better tree growth in litter-treated soil resulted in higher K uptake from the pot soil. Further, the K status of the soil was also found better when poplar was grown in association with turmeric as compared to other treatments.

Table 6. Effect of litter levels and intercrop treatments on organic carbon, phosphorus and potassium contents of the pot soil

Treatment	Litter levels L0			L1			L2			Mean		
	OC (%)	P (ppm)	K (ppm)	OC (%)	P (ppm)	K (ppm)	OC (%)	P (ppm)	K (ppm)	OC (%)	P (ppm)	K (ppm)
P0	0.25	10.5	41.8	0.29	10.4	40.2	0.48	10.6	39.2	0.35	10.5	40.4
PC	0.27	9.8	42.3	0.35	9.7	39.0	0.42	10.1	37.8	0.34	9.8	39.7
PG	0.27	9.9	41.0	0.30	9.9	39.8	0.48	10.0	39.5	0.37	9.9	40.1
PT	0.27	10.2	43.4	0.35	10.5	42.6	0.43	10.6	42.0	0.34	10.4	42.7
Mean	0.27	10.1	42.1	0.32	10.1	40.4	0.45	10.3	39.6	-	-	-

CD ($p < 0.05$) for:

		OC	P	K
crops (C)	=	ns	0.3	1.0
litter (L)	=	0.03	ns	0.8
C x L	=	0.05	ns	1.7

Journal of Tropical Forest Science 9(4): 536 - 545 (1997)

Conclusion

Addition of poplar litter to alkali soils results in better tree and intercrop establishment and also improves the fertility status of such soils. However, management implications such as collecting litter under established tree plantations and its application at another site will have to be considered before making recommendations for field scale application.

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