Edible forage yield and nutritive value of poplar and willow

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Abstract
Poplar and willow on farms are a potential source of supplementary forage during summer. To incorporate poplar and willow into farm feed budgets, a method is needed to non-destructively estimate the edible forage yield of the trees. Also needed is an estimate of the nutritive value of the forage. Previously uncut trees on hill farms in the lower North Island were measured and a relationship between tree forage yield and diameter of the trunk at breast height (DBH, 1.4 m) was developed. The DBH was from 5 to 32 cm and the forage yield from 1 to 66 kg dry matter (DM)/tree. Nutritive value of poplar and willow (metabolisable energy 8–9 MJ/kg DM) was similar to that of normal summer pasture, but was lower in fibre and higher in soluble carbohydrate, and of higher nutritive value than drought pasture. The concentrations of the secondary chemicals condensed tannins and phenolic glycosides were high in poplars and willows, and they have some positive effects on livestock performance, but their role requires further research. It was concluded that poplar and willow provide forage of sufficient quantity and quality to warrant using them as supplements to pasture for feeding to livestock during summer droughts.

Introduction
Poplars and willows planted on farms represent an under utilised source of supplementary forage (Wall *et al*. 1997). Some farmers have long used poplar and willow as supplementary feed during summer, but have been uncertain about the quantity of forage they harvested from a tree. For this tree forage (browse) to be used efficiently it is essential that the quantity and quality of the feed available for livestock be estimated, so it can be included in daily and seasonal feed budgets. Previous research has shown that the yield of edible forage (leaves plus stem < 5 mm diameter) per tree from widely spaced trees ranges from 1–25 kg dry matter (DM) per tree depending on tree age (Kemp *et al*. 2001), and up to 5.9 t DM/ha is produced from densely planted fodder blocks (Hathaway 1986). Kemp *et al*. (2001) suggested that diameter at breast height of the trunk (1.4 m above ground, DBH), or trunk circumference, was suitable for predicting forage yield per tree.

Nutritive value of poplar and willow is similar to normal summer pasture in the same environment, and better than summer drought pasture (McCabe and Barry 1988, Kemp *et al*. 2001). Poplar and willow contain secondary chemicals, particularly condensed tannins (CT) and phenolic glycosides. These chemicals decrease defoliation by sheep (McKinnon *et al*. 2000), possums (Edwards 1978) and insects (Wait *et al*. 1998) when in high concentrations, but can also have beneficial effects on sheep. Condensed tannins can increase protein utilisation when present in forage legume species (Barry and McNabb 1999), and CT-containing poplar have increased lambing percentage when fed as a supplement to drought pasture (McWilliam *et al*. 2002). This paper shows how to estimate the quantity of forage in poplars and willows and provides information on the nutritive value and concentration of secondary chemicals in poplars and willows. Previously unpublished data are used to present an up to date progress report on knowledge about the forage value of poplars and willows and to identify where further research is required.

Methods

The trees used for forage dry matter (DM) measurements were previously uncut Veronese poplar (*Populus deltoides* x *nigra*) and Tangoio willow (*Salix matsudana* x *alba*) growing on hill farms in Wairarapa, central Hawke's Bay, Manawatu (Aokautere) and upper Rangitikei (Taihape). The trees were measured in January and February of 2000, 2002 and 2003. Thirty-two Veronese poplar and 26 Tangoio willows were cut at shoulder height and the edible forage removed and weighed on site. Edible forage was defined as all leaves plus the attached stems of 5 mm diameter or less. A sub-sample was dried at 70°C in a forced draught oven for at least 48 hours to determine dry weight.

The nutritive and secondary chemical concentrations acknowledged to Matheson and McWilliam were on poplar and willow forage sourced from Akura Nursery, Masterton, and the Douglas and Kemp material was from farms near Masterton, Tikikino, Wairoa and Taihape and was collected over three days in December 2002 and in March 2003. All material was kept on ice while being transported to the laboratory. The material was analysed using standard laboratory methods at the Animal Nutrition Laboratory, Massey University and at the AgResearch Grasslands laboratory.

Results and discussion

Edible dry matter

The measured edible DM per tree in Tangoio willow and Veronese poplar was related exponentially to the diameter at breast height (DBH) of the trunk ($p < 0.001$, Figures 1 and 2). The general relationship was similar for both willow and poplar, but the measured values were more variable for poplar than willow at greater DBH values (Figures 1 and 2). The fitted functions were used to provide the predicted values for forage DM per tree presented in Table 1.

Figure 1. Relationship between diameter at breast height (1.4 m, DBH) of the tree trunk and the forage mass per tree based on leaves plus stems < 5 mm diameter for Veronese poplar (n = 32, p < 0.001).

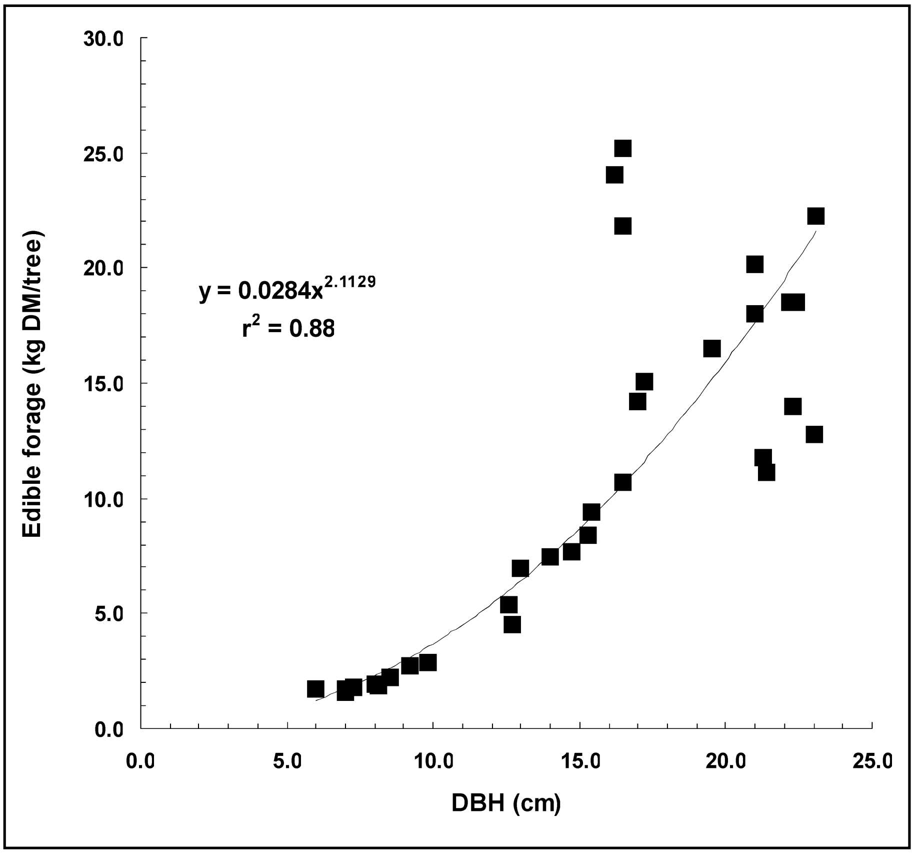
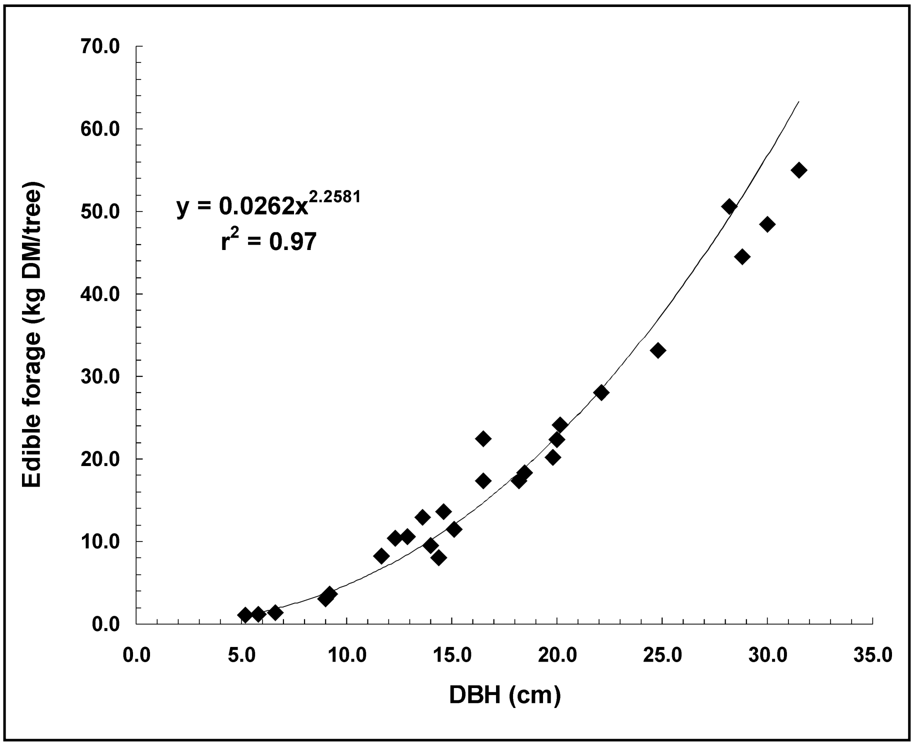


Table 1 provides a practical tool for estimating the quantity of forage (leaves plus stems < 5 mm diameter) from either the DBH or circumference (at 1.4 m above ground level) of Tangoio willow and Veronese poplar. When compared at any given DBH, Tangoio willow had more forage than Veronese poplar, and the difference increased as DBH increased (Table 1). At 5, 10 and 20 cm DBH, the predicted edible DM for Tangoio willow was 1.0, 4.9 and 22.9 kg DM/tree, respectively, and for Veronese poplar was 0.9, 3.7 and 15.9 kg DM/tree, respectively (Table 1). That is, Tangoio willow had 44% more edible DM per tree than Veronese poplar at 20 cm DBH (Table 1). These edible forage yields are similar to those based on three trees each of Veronese poplar and Tangoio willow determined by Kemp *et al*. (2001).

Figure 2. Relationship between diameter at breast height (1.4 m, DBH) of the tree trunk and the forage mass per tree based on leaves plus stems < 5 mm diameter for Tangoio willow (n = 26, p < 0.001).



The maximum DBH for the poplars and willows was chosen for safety and aesthetic reasons. Trees with a DBH greater than 30 cm are often difficult to harvest safely on hill slopes, and to feed to stock. Disposal of large trunks can be time consuming, and the trunks can restrict access around a paddock. Also, farmers tend to be reticent to harvest large trees that have become part of the farm landscape. A large Kawa poplar (52 cm DBH) that needed to be removed near Taihape yielded 70 kg of edible DM (unpublished data).

From Table 1 some simple examples can be developed to demonstrate the quantity of tree forage available on a farm. At 50 trees/ha over 20 ha, for example, Tangoio willow of 15 cm and 20 cm DBH would provide 12,000 kg DM and 22,900 kg DM, respectively. If ewes were supplemented with 0.2 kg DM of willow per day then 3,000 ewes would be supplemented for 20 days. This would require harvesting 50 trees per day, or 26 trees per day for trees with 20 cm DBH.

Poplars and willows harvested for fodder regrow, particularly if the cutting height

Table 1. Predicted forage dry matter (DM) per tree for Tangoio willow and Veronese poplar using either trunk circumference or diameter at breast height (DHB) measured 1.4 m above ground level. (n.d. not determined)

Circumference (cm)	DBH (cm)	Tangoio (kg DM/tree)	Veronese (kg DM/tree)
15.7	5	1.0	0.9
18.8	6	1.5	1.3
22.0	7	2.2	1.7
25.1	8	2.9	2.3
28.3	9	3.8	2.9
31.4	10	4.9	3.7
34.6	11	6.0	4.5
37.7	12	7.3	5.4
40.8	13	8.7	6.4
44.0	14	10.3	7.5
47.1	15	12.0	8.7
50.3	16	13.9	9.9
53.4	17	15.9	11.3
56.5	18	18.1	12.8
59.7	19	20.4	14.3
62.8	20	22.9	15.9
66.0	21	25.5	17.7
69.1	22	28.3	19.5
72.3	23	31.3	21.4
75.4	24	34.4	23.4
78.5	25	37.7	n.d.
81.7	26	41.1	n.d.
84.8	27	44.8	n.d.
88.0	28	48.6	n.d.
91.1	29	52.5	n.d.
94.2	30	56.7	n.d.
97.4	31	61.0	n.d.
100.5	32	65.5	n.d.

is above browsing height of sheep (1.3 m) or cattle (2 m). Douglas *et al*. (2003) found that average regrowth of edible biomass from six Tangoio willow trees (DBH = 29 cm) in central Hawke's Bay after one year was 0.8 kg DM/tree, but measurements on the regrowth production of harvested trees are scarce and more are required.

Table 2 shows the predicted quantity of edible DM in small branches (2–5 cm) of Tangoio willow and Veronese poplar. Tangoio and Veronese poplar branches of 5 cm diameter had 1.4 and 1.6 kg DM/branch, respectively, which was similar to the quantity of edible DM in a tree of similar diameter (Figures 1 and 2).

The data in Tables 1 and 2 illustrate the forage available from widely spaced willows and poplars planted on farms for soil conservation or other reasons. The pruning or thinning of poplars and willows as they age has advantages other than providing forage in dry summers. Pruning the lower branches of trees decreases the area of the pasture directly shaded below the trees, and thereby increases the pasture production between widely spaced trees (Devkota *et al*. 2001). Similarly, thinning of poplar and willow trees before they become unmanageably large allows a balance to be maintained between sufficient trees for erosion control, and excessive tree canopy closure that decreases pasture production through shading.

Table 2. Predicted edible dry matter per branch of Tangoio willow and Veronese poplar using functions from Kemp *et al* (2001); where basal diameter of the branch is measured immediately before the branch joins the trunk.

Basal diameter (cm)	Basal circum. (cm)	Tangoio (kg DM branch)	Veronese (kg DM branch)
2.0	6.3	0.16	0.28
2.5	7.9	0.36	0.50
3.0	9.4	0.57	0.72
3.5	11.0	0.77	0.94
4.0	12.6	0.98	1.16
4.5	14.1	1.18	1.38
5.0	15.7	1.39	1.60

High density fodder tree blocks (2,500–16,000 trees /ha) have produced from 1.4 to 5.7 t DM/ha of edible forage per year over the first 3–5 years (Hathaway 1986; Douglas *et al*. 1996; Oppong *et al*. 1996, 2001). The DM yield from recently established willow fodder blocks (6,000 trees/ha) is reported by Douglas *et al*. (2003) in these Proceedings.

A major consideration with fodder tree blocks is the method of harvesting the forage. Manual cutting is laborious, whereas browsing the trees with livestock requires developing a management regime that keeps tree height accessible to livestock yet does not damage the trees. Research is currently being undertaken in this area.

Nutritive value

The nutritive value of poplar and willow forage is broadly similar (Tables 3 and 4). For example, the average organic matter digestibility (OMD) of poplars and willows in Tables 3 and 4 was 69.7 ± 2.82% and 69.2 ± 2.01% (mean ± SEM), respectively. Crude protein, ash and metabolisable energy (ME) concentrations were also similar for poplar and willow, with the exception of the low ash concentration (1.6%) in Kinuyanagi relative to Tangoio willow, and to poplars (Tables 3 and 4).

Although estimates of OMD for poplars and willows reported in the literature have usually been 60–70% (McCabe and Barry 1988; Oppong *et al*. 1996; Kemp *et al*. 2001; Moore *et al*. 2003), recent *in vivo* OMD measurements of poplar and willow have shown that these *in vitro* estimates of OMD are over estimated by approximately 10% (T.N. Barry and E.L. McWilliam, pers. comm.). However, even when OMD for

Table 3. Nutritive value of edible DM (leaf plus stem < 5mm diameter) of willows. OMD is organic matter digestibility, ME is metabolisable energy and n.d. is not determined.

Cultivar/season	Crude Protein (% DM)	OMD (%DM)	Ash (%DM)	ME (MJ/kg DM)
Tangoio[1]	17.1	69.2	n.d.	9.9
Tangoio[2]	13.2	71.4	6.4	10.3
Kinuyanagi[2]	7.1	65.0	1.6	9.7
Willow/Dec[3]	11.9	71.4	4.7	10.4
Willow/March[3]	8.4	65.0	3.3	9.6
Willow/Spring[4]	17.0	78.8	7.6	11.6
Willow/Summer[4]	14.2	63.5	6.4	9.8

1 McWilliam (pers. comm.), 2002, season mean,
2 Douglas (pers. comm.) 2003, December and March
3 Douglas (pers. comm.), 2003, mean of Tangoio and Kinuyanagi
4 Matheson (pers. comm.), 2000, mean of Tangoio, Matsudana, Moutere

Table 4. Nutritive value of edible DM (leaf plus stem < 5mm diameter) of poplars. OMD is organic matter digestibility, ME is metabolisable energy and n.d. is not determined.

Cultivar/season	Crude Protein (%DM)	OMD (%DM)	Ash (%DM)	ME (MJ/kg DM)
Veronese[1]	17.8	65.7	n.d.	9.7
Veronese[2]	16.4	62.4	n.d.	9.2
Veronese/Spring[3]	18.9	77.9	7.3	11.4
Veronese/Summer[3]	17.9	68.7	8.7	10.3
Poplar/Spring[4]	19.6	78.6	8.3	11.4
Poplar/Summer[4]	14.9	65.1	7.8	9.9

1 McWilliam (pers. comm.), 2001, season mean, stem diameter < 7mm.
2 McWilliam (pers. comm.), 2002, season mean, stem diameter < 7mm.
3 Matheson (pers. comm.), 2000.
4 Matheson (pers. comm.), 2000, mean of nine poplar cultivars.

poplar and willow is adjusted, it is similar to, or greater than, the OMD of normal summer pastures (55–65%), and greater than the OMD of drought pasture (52–55%). The ME values in Tables 3 and 4 and in the literature will also be over-estimates as they are calculated from digestibility measurements.

The OMD, crude protein and ME of poplar and willow forage were significantly higher in spring than summer, but the forage is more likely to be used in summer ($p < 0.05$, Tables 3 and 4). Nevertheless, browsing of poplar and willow fodder trees in spring to control their height would provide forage with a moderate nutritive value. The decline over the growing season in the OMD of edible tree forage by approximately 10% is mainly due to the maturing of the thin stems. Thin stems of poplars (*P. nigra*), for example, had a digestibility of 32% compared with 63% for the leaves (Orensanz *et al*. 1983). The digestibility of poplar and willow leaves only decreases by about 3% as they mature over the growing season (Kemp 2001).

Although the green leaves of poplars and willows have a higher nutritive value than the edible forage (leaves plus < 5 mm diameter stems), livestock will always also eat the stems (Kemp *et al*. 2001). Senesced or dead leaves on the ground have a low nutritive value, with OMD 50% and ME 7–8 MJ/kg DM, but livestock should be encouraged to eat freshly fallen leaves to lessen their smothering effect on pasture growth (Kemp *et al*. 2001). Livestock also eat the bark on stems and trunks of poplars and willows. Bark is of low nutritive value with *in vitro* digestibility of 55–65%, ME of 9 MJ/kg DM, and crude protein of 3–5%, partly offset by a readily fermentable carbohydrate concentration of 15–16% (Kemp *et al*. 2001).

The fibre concentration (NDF and ADF) of the edible forage of poplar and willow was lower than in summer drought pasture (Table 5). Similarly, Douglas and Kemp (unpublished data) measured 26% ADF and 31% NDF in willow forage (cf. Table 5). The ratio of readily fermentable carbohydrate to structural carbohydrate was higher in poplar and willow than summer pasture, largely due to the presence of phenolic glycosides (salicin and others) in the tree forage. The 11.6% and 17.8% of phenolic glycosides in poplar and willow, respectively, provide extra soluble carbohydrate

Table 5. Carbohydrate and secondary chemical concentrations in summer drought pasture, Veronese poplar and Tangoio willow, equivalent to the diet selected by ewes. Poplar and willow samples were leaf plus, <7mm and <5mm stem diameter, respectively. CHO: carbohydrate; ADF: acid detergent fibre; NDF: neutral detergent fibre. (McWilliam, pers. comm.).

Chemicals	Drought Pasture (% DM)	Poplar (% DM)	Willow (% DM)
Carbohydrates:			
Water soluble CHO	10.2	15.6	12.3
Pectin	0.9	3.3	3.6
NDF	59.6	39.0	38.1
ADF	30.1	26.1	26.4
Readily fermentable CHO: Structural CHO[1]	0.20	0.68	0.65
Secondary chemicals:			
Lignin	3.8	11.0	13.4
Condensed tannins	0	0.7	5.2
Salicin	0	1.7	0.5
Other phenolic glycosides	0	9.9	17.3

[1] (Water soluble CHO + pectin) / (cellulose + hemicellulose) (i.e. NDF– lignin)

by breaking down to glucose when digested. The relatively higher soluble carbohydrate concentration and lower fibre concentration of poplar and willow, than summer drought pasture, make them an effective supplementary feed to balance the soluble carbohydrate and fibre concentrations of the summer pasture.

The ash concentration of poplar leaves is higher in Ca, K, Mg and Zn than pasture (A. Wall pers. comm.). For example, the Mg and Zn concentrations of poplar leaves in the Orua Valley near Kiwitea were 0.52% and 0.011%, respectively. This contrasted with 0.14–0.34% Mg and 0.006% Zn in nearby pasture. For willow leaves, only the Zn concentration is higher than in pasture (Douglas *et al.* 1996).

Secondary chemicals

A major difference between the chemical composition of poplar and willow forage and summer pasture is the presence of secondary chemicals. The main secondary chemicals present in poplar and willow forage are phenolic glycosides (e.g. salicin) and condensed tannins. The effects of condensed tannins on sheep performance are beginning to become apparent, and include increased protein utilisation from the forage, and an increased lambing percentage in some circumstances (Min *et al*. 2001; McWilliam *et al*. 2002). However, the direct effects of CT, and salicin and the other phenolic glycosides present in poplar and willow forage on livestock, have not been determined.

The condensed tannin concentration of the edible biomass is commonly 0.3–2% for poplar cultivars and 1–6% for willow cultivars (Table 5, Kemp *et al*. 2001). Some cultivars of poplars and willows have higher concentrations, with Kinuyanagi willow measured at 20% CT (Oppong *et al*. 2001) and Louisa Avanza poplar at 4.2% CT in spring (Matheson, unpublished data). The bark of Tangoio willow had 8% and that of Veronese poplar 2% CT (Kemp *et al*. 2001).

The concentration of 0.5% and 1.7% salicin in Tangoio willow and Veronese poplar, respectively, was in the range measured in other countries (Wait *et al*. 1998), but salicin is only a minor component of the phenolic glycosides found in poplar and willow (Table 5). The identity, concentration and role of phenolic glycosides requires further research. High salicin concentration reduces the palatability of poplar cultivars to sheep (McKinnon *et al*. 2000) and possums (Edwards 1978), and salicin and other phenolic glycosides restrict insect consumption of poplars and willows (Wait *et al*. 1998).

Conclusions

The poplars and willows planted on farms for soil conservation, or as fodder blocks, represent an important source of supplementary feed during summer droughts, which can now be included in a farm's feed budget through estimating the quantity of edible forage in trees and the nutritive value of the forage using the data presented in this paper. The quantity of edible forage in poplars and willows can be estimated by measuring the diameter or the circumference of the trunk at breast height (1.4 m).

The organic matter digestibility (55–65% OMD) and metabolisable energy (8–9 MJ/kg DM) of poplar and willow forage are approximately the same as normal summer pasture, but considerably greater than for summer/autumn drought pasture. The crude protein concentration (15–18%) of poplar and willow forage is also in the range for summer pasture, whilst the concentration of readily fermentable carbohydrate is greater in poplar (19%) and willow (16%) forage than in summer drought pasture (10–12%). The fibre concentration of poplar (37% NDF) and of willow (38% NDF) is lower than that of summer pasture (45–60% NDF). The concentration of the total secondary chemicals in willow (36%) and poplar (23%) is 5 to 10 times greater than in pasture (4%). Overall, their concentrations of protein, CT and phenolic glycosides make willow and poplar excellent supplements to low quality drought pasture that is high in fibre.

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