Uganda Journal of Agricultural Sciences, 2006, 12(1):46-54 ISSN 1026-0919

Evaluation of *Alnus* provenances against *Septoria* brown leaf spot and insect damage during early growth stages in Kabale district, Uganda

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Abstract

Host plant resistance offers one of the most appropriate pest control strategies for resource poor farmers. This study evaluated 10 Alnus acuminata and A. nepalensis provenances against Septoria brown leaf spot and insect infestations under nursery and field conditions in Kabale district, Uganda. All provenances examined were susceptible to Septoria brown leaf spot, indicating limited scope for selecting for resistance against the disease. In contrast, significant variations occurred between provenances in the incidence and severity of Apis mellifera leaf perforations, with provenances of Alnus acuminata more severely attacked by the insect than those of A. nepalensis. Damage by other insects was generally low in the nursery and moderate in the field. Application of a mixture of insecticide and fungicide in the nursery significantly improved seedling survival and growth in the nursery and field, implying that insects and fungi are serious pests of Alnus seedlings. Seedling survival in the nursery and field was generally good for A. acuminata provenances from Uganda and Guatemala, and A. nepalensis from Rwanda, China and Nepal, but was poor for A. acuminata provenances from Columbia. Alnus acuminata provenances were generally taller than A. nepalensis provenances both in the nursery and in the field.

Key words: Alnus species, diseases, insect pests, pest management, provenance trial

Introduction

Alnus species have recently received considerable attention as important agroforestry trees in tropical highlands. Presently, two *Alnus* species, *A. acuminata* HBK and *A. nepalensis* D. Don., are cultivated in Uganda with increasing adoption for agroforestry especially in the Kigezi highlands (van Houten, 1997). These exotic species provide the much-needed fuelwood and stakes for climbing beans while the main stem is left to develop into pole or saw log. In addition, the *Alnus* species are important for fixing atmospheric nitrogen and are well suited for improving soil fertility, restoration of degraded land and for protection of watershed (Russo, 1995; Neil, 1997).

However, one of the major challenges facing the cultivation of the *Alnus* species is the increasing evidence of pest infestations. *Alnus nepalensis* recently suffered from defoliation up to 100% due to *Gazalina chrysolopha* Kollar (Notodontidae) in Bhutan (Raman, 1998). *Scolytodes alni* Wood (Sclolytidae) is a serious borer of *A. acuminata* in Costa Rica (Cornelius and Masis, 1995). In Uganda, brown leaf spot caused by *Septoria alni* Sacc. and an unidentified *Septoria* strain (*alni*?), and leaf perforations, mainly caused by *Apis mellifera* L. (Apidae) are damages reported on *Alnus* in nurseries and the field respectively (Roux, 1999; Nyeko *et al*., 2002a; Nyeko *et al*., 2002b). These foliar infestations result in a reduction in the photosynthetic area of surviving leaves and premature abscission of severely affected leaves, and may ultimately reduce the growth rate of *Alnus* (Nyeko, 2001). In light of the increasing demand for *Alnus* species for agroforestry, appropriate control practices against such pests are needed.

In a review of insect pest problems in agroforestry, Rao *et al*. (2000) recommended genetic resistance as the most appropriate pest control measure for agroforestry trees that produce low value products and are used for service function and improving soil fertility. Unfortunately, very little is known about variation among *Alnus* provenances in susceptibility to pathogens and insect pests in the tropics. Cornelius and Masis (1995) and Cornelius *et al*. (1996) found a Guatemalan *A. acuminata* provenance more susceptible to *Scolytodes alni* than local provenances of the species in Costa Rica. There is apparently no published report evaluating *Alnus* provenances against insect pests and pathogens in Africa. The objective of this study was to screen *Alnus acuminata* and *A. nepalensis* provenances against *Septoria* brown leaf spot, *Apis mellifera* and other leaf damaging insects under nursery and field conditions. Such information is extremely important for provenance selection and/or development of highly productive clones that are well adapted to local environmental conditions.

Materials and Methods

Study area

This study was conducted at the Bugongi nursery of the World Agroforestry Centre's (ICRAF) Kabale research station and in the field at Kachwekano, Kabale district (0^{o}16' S, 29^{o}57' E), Uganda. Kabale lies at approximately 2000 m above sea level. The annual rainfall pattern in the district ranges between 1,000 mm to 1,480 mm per annum and is bimodal with peaks in March and April, and October and November. A brief dry spell occurs in January and a drier period from June to August. The monthly temperature averages 17.5 ^{o}C, which sometimes drops to about 10 ^{o}C at night (Rwabwoogo, 1997).

Nursery experiment

Seeds of 10 *Alnus* provenances (Table 1) were sown in plastic trays that were three-quarter filled with moist sand in August 1999. The seeds germinated from 10 to 20 days after sowing (DAS), and were pricked-out 60 to 61 DAS into 22.5 cm x 9.5 cm black polythene pots filled with 3:1 mixture of soil obtained from nearby *Eucalyptus* plantation and sand respectively. The experiment was laid out 14 days after pricking out in order to exclude seedling mortality due to pricking-out injury. A randomised block design with three replications and two treatment levels, pesticide treated and untreated (water control), were used. For each provenance, 20 seedlings with no visible insect and disease damage were randomly selected and arranged into a sampling plot. However, only 10 seedlings per plot were available for Jorulensis1 and 10 seedlings per treatment for Jorulensis2 due to poor germination and survival of seedlings of these provenances. Consequently, Jourlensis2 seedlings were included only for casual observations. Spacing of 1.7 m between plots in a block and 2 m between blocks were established to facilitate nursery operations as well as reduce pesticide drift while spraying.

Table 1. *Alnus acuminata* and *A. nepalensis* provenances evaluated in Kabale district, Uganda.

Provenance	Country of origin	Seed supplier
A. acuminata		
Kabale	Uganda	ICRAF-Kabale, Uganda
Chimaltenago	Guatemala	ICRAF-Nairobi, Kenya
Acuminata1	Costa Rica	Poplar research station, Belgium
Jorulensis1	Colombia	Poplar research station, Belgium
Jorulensis2	Colombia	Poplar research station, Belgium
Nepalensis 2U*	-	Poplar research station, Belgium
A. nepalansis		
Rwanda	Rwanda	ICRAF-Rwanda
Nepal	Nepal	Regional seed centre, Nepal
Nepalensis 0	-	Poplar research station, Belgium
Nepalensis1 no. 636	China	Poplar research station, Belgium

Information not provided by seed supplier; *, an *A. acuminata* provenance indicated as Nepalensis by seed supplier.

The pesticides consisted of a mixture of Salut (chlorpyrifos and dimethoate) and benomyl. Starting November 1999, the pesticide mixture was applied only to *Alnus* seedlings in the plots for 'pesticide treated' treatment at 4-week interval using a 600 cc. hand sprayer. The pesticide spray was prepared by mixing benomyl, Salut and water in the ratio of 2 g:3 ml:2 litres respectively following the pesticide container label instructions, and the mixture applied at 0.25 litres/m^2. Similarly, water was applied to the water control (untreated) seedlings during every pesticide treatment occasion. In order to avoid false positives for *Septoria* infection (i.e. susceptible provenances escaping infection by the fungus), two *A. acuminata* seedlings naturally infected by the fungus were placed in each sampling plot. Inoculum seedlings used in the pesticide treated treatment were thoroughly sprayed with a mixture of benomyl and Salut prior to their inclusion into the sampling plots. The seedlings were watered once daily, except on rainy days when sufficient moisture was available. Weeds that emerged at the experimental site were removed monthly by hoeing while those that emerged in the pots containing the seedlings were hand-pulled weekly.

Seedling height and root collar diameter (RCD), and the incidence and severity of *Septoria* brown leaf spot, *A. mellifera* and any other leaf damaging insects were assessed on all surviving seedlings at 7 months after sowing. For every seedling, leaves having symptoms of each pest type (Septoria brown leaf spot, *A. mellifera* or other insects) were counted to indicate pest incidence. Similarly, the severity of each pest type was scored on every seedling using severity scales modified from Odera (1991) as follows: 1 (no visible damage), 2 (0-5% foliar damage), 3 (5-25% foliar damage), 4 (25-50% foliar damage including damaged shoot tip), 5 (50-75% foliar damage including damaged shoot tip) and 6 (over 75% foliar damage including damaged shoot tip).

Field evaluation

The field experiment was established in April 2000 in a randomised block design. The experiment was set up on two adjacent terraces with a smaller lower terrace comprising a block, and a longer upper terrace consisting of two blocks. Within the upper terrace, one block was established in a sweet potato (Ipomoea batatas L.) garden and the other on a fallow portion of the terrace. In the lower terrace, *Alnus* seedlings were also planted amongst a sweet potato crop. Each block was divided into line plots corresponding to the randomisation in the nursery experiment where the seedlings were raised. A spacing of 2 m was used between and within plots. Every plot consisted of five seedlings randomly selected from the corresponding experimental plot in the nursery. However, only 10 seedlings of provenances Jorulensis1 and Nepalensis 2U were available for each treatment, and were consequently included in only two blocks. Even worse was the survival of Jorulensis2 where only five seedlings were available at outplanting. The seedlings of this provenance were consequently planted only in one block for casual observations. Seedlings within the potato gardens were weeded in May 2000 as the potato was harvested while those in the fallow block were spot-weeded in order to minimise the weeding cost. No pesticide treatment was applied in the field. Seedling survival, height and RCD, and pest severity were assessed, as described for the nursery experiment, at outplanting, and four and 12 Months After Outplanting (MAO).

Data analysis

Analysis of variance (ANOVA) in Minitab statistical package was used to compare *Alnus* provenances and treatments (pesticide treated and untreated) in pest incidence and severity, and seedling height and RCD. Prior to analysis, non-normally distributed data were square root or $\log_{10}x$ transformed upon checking for normality using Anderson-Darling test. Seedling survival was expressed as the proportion of total seedlings at the onset of each experiment (nursery or field) that were alive at a particular assessment occasion, and analysed using ANOVA. Provenance and pesticide treatment means for the different variables were compared for level of significance by the least significance difference (LSD) at 5% probability level. Because of very poor survival, provenances Jorulensis1 and

Table 2. Survival, height and root collar diameter (RCD) of pesticide treated and untreated *Alnus acuminata* and *A. nepalensis* provenances at 7 months in the nursery, and 4 and 12 months after outplanting (MAO) in Kabale district, Uganda.

Provenance and pesticide treatment	Survival (%)			Growth					
	Nursery	4 MAO	12 MAO	Nursery		4 MAO		12 MAO	
				Height (cm)†	RCD (mm)	Height (cm)	RCD (mm)	Height (cm)	RCD (mm)
A. acuminata									
Kabale	**91.7^{ab}**	**96.7^{a}**	**96.7^{a}**	**30.2^{a}**	**4.8^{a}**	**63.8^{a}**	**11.0^{a}**	**181.4^{a}**	**36.9^{a}**
Chimaltenago	86.7^{b}	80.0^{b}	80.0^{b}	26.0^{b}	4.3^{a}	52.9^{b}	10.0^{ab}	160.1^{ab}	31.4^{b}
Acuminata1	58.3^{c}	46.7^{c}	30.0^{c}	13.2^{c}	2.6^{bc}	35.9^{c}	6.2^{c}	141.0^{b}	21.5^{cf}
Jorulensis1	38.3^{d}	-	-	12.3^{cd}	2.4^{b}	-	-	-	-
Nepalensis 2U	38.3^{d}	33.3^{d}	26.7^{d}	11.7^{de}	1.9^{c}	27.7^{d}	4.2^{d}	102.5^{c}	16.2^{d}
A. nepalensis									
Rwanda	**92.5^{a}**	**80.0^{b}**	**76.7^{b}**	**9.7^{f}**	**3.5^{de}**	**22.5^{d}**	**9.4^{be}**	**93.9^{c}**	**24.7^{ce}**
Nepal	65.0^{e}	80.0^{b}	66.7^{e}	10.0^{fe}	2.7^{b}	32.5^{c}	7.5^{cf}	154.3^{ab}	24.8^{ce}
Nepalensis 0	75.8^{f}	76.7^{b}	76.7^{b}	10.4^{fe}	3.7^{d}	22.4^{d}	8.1^{ef}	91.9^{c}	26.5^{e}
Nepalensis1 no. 636	80.8^{f}	66.7^{e}	66.7^{e}	11.0^{e}	2.9^{be}	28.5^{d}	7.5^{cf}	106.5^{c}	19.3^{df}
Pesticide treatment									
Untreated	69.1	62.5^{a}	58.3^{a}	12.3^{a}	3.0^{a}	32.6^{a}	7.4^{a}	124.6	23.6^{a}
Treated	70.4	77.5^{b}	71.7^{b}	14.5^{b}	3.4^{b}	39.0^{b}	8.5^{b}	133.3	26.8^{b}

For each of provenance and pesticide treatment, means followed by different letters within a column differed significantly at 5% probability. -, missing data.

Jorulensis2 were excluded from the analysis of the field evaluation data.

Results

Seedling survival, height and root collar diameter (RCD)

Seedling survival in both nursery and field studies varied markedly between *Alnus* provenances (Table 2). At about seven months after sowing, provenances Kabale, Chimaltenago, Rwanda and Nepalensis1 no. 636 showed >80% survival, but Jorulensis1 and Nepalensis 2U exhibited poor seedling survival (< 50%). Although the survival of pesticide treated and water control seedlings in the nursery was statistically similar ($P > 0.05$), the former had significantly higher ($P < 0.05$) survival than the latter in the field. At 12 MAO, treated seedlings of provenances Kabale, Chimaltenago, Rwanda, Nepalensis0 and Nepalensis1 no. 636 displayed good (>70%) survival. A total of three seedlings, two Nepalensis 2U and one Acuminata1, were apparently killed by unidentified termite species (Isoptera: Termitidae) which severely damaged the roots of the seedlings in the field.

Significant ($P < 0.05$) variations in height and RCD were evident between the provenances (Table 2). At 7 months of growth in the nursery, *A. acuminata* seedlings were significantly taller ($P < 0.001$) than *A. nepalensis* seedlings, but seedlings of these species exhibited statistically similar RCD ($P > 0.05$). Provenance Kabale that showed the fastest height growth also exhibited the highest growth in RCD throughout the study (Table 2). Conversely, provenance Nepalensis 2U showed the lowest RCD at all assessment dates. Provenance Nepal was the tallest *A. nepalensis* provenance at all assessments, attaining up to 154 cm at 12 MAO. Significant ($P < 0.05$) effects of nursery pesticide treatments on seedling height were evident only in the nursery and at four MAO, but not at 12 MAO. This suggests that untreated seedlings compensated in height growth over time.

Table 3. Incidence (percentage of total leaves per seedling damaged) and severity of *Septoria* brown leaf spot, *Apis mellifera* and other insects on *Alnus* provenances at 7 months of growth in ICRAF Bugongi nursery, Kabale district, Uganda.

Provenance and Pesticide treatment	Total leaves per seedling	Pest incidence (%)			Pest severity		
		Brown spot	*A. mellifera*	Other insects	Brown spot	*A. mellifera*	Other insects
A. acuminata							
Kabale	44.2^{a}	32.1^{a}	0.3^{a}	0.9^{a}	2.9^{a}	1.1^{a}	1.3^{a}
Chimaltenago	37.8^{a}	34.1^{ab}	0.2^{b}	0.8^{a}	3.1^{a}	1.1^{a}	1.2^{bc}
Acuminata1	16.8^{bc}	36.7^{b}	0.0^{c}	0.8^{a}	3.0^{a}	1.0^{b}	1.1^{d}
Jorulensis1	18.9^{b}	23.1^{c}	0.0^{c}	0.0^{b}	2.5^{b}	1.0^{b}	1.0^{e}
Nepalensis 2U	10.7^{c}	28.7^{a}	0.0^{c}	0.1^{b}	2.5^{b}	1.0^{b}	1.0^{e}
A. nepalensis							
Rwanda	22.3^{b}	20.4^{cd}	0.0^{c}	0.8^{a}	2.1^{c}	1.0^{b}	1.2^{bd}
Nepal	19.8^{b}	19.4^{d}	0.0^{c}	2.0^{c}	2.1^{c}	1.0^{b}	1.3^{ac}
Nepalensis 0	23.2^{bd}	21.7^{c}	0.0^{c}	0.6^{a}	2.2^{c}	1.0^{b}	1.2^{d}
Nepalensis1 no.636	29.0^{d}	24.2^{c}	0.0^{c}	1.7^{c}	2.4^{b}	1.0^{b}	1.3^{a}
Pesticide treatment							
Untreated	22.4^{a}	57.8^{a}	0.02^{a}	1.0	3.7^{a}	1.0	1.2
Treated	26.9^{b}	6.6^{b}	0.00^{b}	0.5	1.7^{b}	1.0	1.1

For each of provenance and pesticide treatment, means followed by different letters within a column differed significantly at 5% probability.

However, pesticide treated seedlings showed significantly higher RCD than untreated ones at all assessment dates.

Pest incidence and severity in nursery

All *Alnus* provenances examined in this study were susceptible to *Septoria* brown leaf spots, although the incidence and severity of the disease were generally higher *on A. acuminata* than *A. nepalensis* provenances (Table 3). The incidence and severity of brown leaf spot was significantly lower ($P < 0.05$) on pesticide treated than untreated seedlings with the highest incidence of the disease (74%) evident on untreated Acuminata1. In contrast, *A. mellifera* damage was observed only on provenances Chimaltenago and Kabale with the highest incidence of only 0.6% observed on untreated Kabale. Similarly, the incidence of other insects, mainly an *Auloserpusia* species (Orthoptera: Acrididae) and larvae of an unidentified Geometridae (Lepidoptera) was low at less than 4% leaf damage, although the insects attacked all provenances (Table 3).

Pest severity in the field

The severity of brown leaf spot decreased between outplanting and four MAO, and increased from four to 12 MAO (Table 4). At 12 MAO, the severity of *Septoria* brown leaf spot was highest on provenance Chimaltenago and lowest on Nepalensis 2U (Table 4). Although the severity of brown leaf spot was significantly lower ($P < 0.05$) on pesticide treated than untreated seedlings at outplanting and four MAO, the severity of the disease was higher on pesticide treated seedlings than untreated ones at 12 MAO. This indicates that the fungicide applied in the nursery was no longer effective against the *Septoria* species that was causing brown leaf spot by 12 MAO.

Generally, the severity of insects was higher at 12 MAO than on any assessment date (Table 4).

Table 4. Average severity of *Septoria* brown leaf spot, *Apis mellifera* and other insects on *Alnus* seedlings at outplanting, and 4 and 12 months after outplanting (MAO) at Kachwekano, Kabale district, Uganda.

Provenance and pesticide treatment	Pest severity								
	Outplanting			4 MAO			12 MAO		
	Brown spot	*A. mellifera*	Other insects	Brown spot	*A. mellifera*	Other insects	Brown spot	*A. mellifera*	Other insects
A. acuminata									
Kabale	2.94[a]	1.12[a]	1.29	1.88[a]	1.07	2.03[ab]	2.55	2.01[a]	3.11
Chimaltenago	3.05[a]	1.10[a]	1.18	1.82[a]	1.13	2.08[a]	2.85	1.58[b]	3.20
Acuminata1	3.02[a]	1.00[b]	1.06	1.34[b]	1.00	1.76[c]	2.15	1.21[c]	3.51
Nepalensis 2U	2.44[b]	1.00[b]	1.06	1.62[c]	1.00	1.16[d]	1.73	1.13[cd]	2.04
A. nepalensis									
Rwanda	2.23[c]	1.00[b]	1.23	2.23[d]	1.00	1.69[e]	2.09	1.04[de]	3.10
Nepal	2.21[c]	1.00[b]	1.38	1.54[c]	1.00	1.83[ce]	2.67	1.00[e]	2.97
Nepalensis 0	2.21[c]	1.00[b]	1.15	2.19[d]	1.00	1.88[bce]	2.26	1.00[e]	2.76
Nepalensis no. 636	2.37[bc]	1.00[b]	1.25	1.83[a]	1.00	2.10[a]	2.20	1.00[a]	2.97
Pesticide treatment									
Untreated	3.69[a]	1.04	1.23	1.91[a]	1.01	1.76	2.59[a]	1.23	2.89
Treated	1.74[b]	1.02	1.16	1.66[b]	1.04	1.83	2.02[b]	1.28	3.96

For each of provenance and pesticide treatment, means followed by different letters within a column differed significantly at 5% probability.

Significant differences (P < 0.05) were evident between provenances in the severity of *A. mellifera*. However, the severity of *A. mellifera* remained low throughout the study with provenances Nepal, nepalensis0 and Nepalensis1 no. 636 showing no damage by this insect species at 12 MAO. In contrast, *A. mellifera* leaf perforation was observed on all *A. acuminata* provenances at 12 MAO with provenance Kabale most severely attacked by the insect (Table 4). Damage due to other insects was mainly defoliation caused by *Phymateus viridipes* (Orthoptera: Acrididae), *Conchotopoda leggei* (Orthoptera: Tettigoniidae) a *Lobotrachelus* species (Coleoptera: Curculionidae) and larvae of an unidentified Geometridae (Lepidoptera).

Discussion

It is important to ascertain whether or under which conditions it is advisable or necessary to use exotic tree species in agroforestry, given the risk that they may be affected by native pests and diseases to which they have not developed resistance mechanism (Rao *et al*., 2000). In the present study, pesticide treated seedlings showed significantly higher survival and growth rates than water control seedlings, indicating the need for control measures against *Septoria* and insect pests on *Alnus* seedlings in the nursery. Several authors have pointed out the need for good seedling growth in nursery for successful subsequent seedling survival and growth when outplanted (Smith *et al*., 1989; Kope *et al*., 1996; Kope and Trotter, 1998). This could especially be of value when selecting seedlings for difficult environments such as areas where crop/weed competition is strong or where there is a premium on the rapid development of a widespread root system to capture water (Salazar, 1986).

All *Alnus* provenances examined in this study were susceptible to *Septoria* brown leaf spot, indicating limited scope for selecting brown spot resistant *Alnus* provenances. In contrast, Kim and Chun (1965) reported *Alnus hirsuta* (Spach) Rupr. variety microphylla from Japan as resistant to *Septoria alni* in South Korea. However, only five provenances each from *A. acuminata* and *A. nepalensis* were examined in this study. Additional *Alnus* provenances should therefore be screened to ascertain if any resistant material against the *Septoria* disease could be found in the *Alnus* species. *A. acuminata* provenances that showed faster growth rates exhibited higher severity of *Septoria* brown-leaf spot in the nursery than those of *A. nepalensis* with relatively slower growth rates. Similarly, Dungey *et al*. (1997) reported greater severity of Mycosphaerella leaf spot on *Eucalyptus* provenances with greater growth rates. Possibly, greater seedling size increased *Septoria conidium* catches and/ or canopy humidity (Kope *et al*., 1996).

Seasonal effects on *Septoria* diseases is well known (Agrios, 1997). In this study, the severity of *Septoria* brown leaf spot declined markedly within four months of outplanting. The May - August 2000 dry season that commenced shortly after outplanting in April 2000 suggests a weather regime unfavourable for the development of severe *Septoria* brown leaf spot (Agrios, 1997). New *Septoria* brown leaf spot infestations in subsequent periods when rainfall was again high, particularly in the first wet season of 2001 (February - April), would explain the increase in severity of the disease recorded at 12 MAO.

Considering the outstanding economic and ecological importance of *A. mellifera* (Roubik, 1989), limited range of measures are available to appropriately control the insect species. Control measures that reduce the population of the insect may be undesirable. In this study, *A. nepalensis* provenances consistently showed very good resistance against *A. mellifera* although the severity of the bee damage was generally low. Variation among tree provenances in honeybee leaf damage has also been reported by Palmberg (1977) who observed that *Populus* provenances from Kansas and Georgia were consistently less severely damaged by honeybees than several other provenances tested in Australia. These results indicate that the use of resistant provenances seems a feasible approach to reducing *A. mellifera* leaf damage on *Alnus* species.

However, provenances of *A. nepalensis* generally showed slower growth rates than those of *A. acuminata*, even when protected against fungi and insects in the nursery. Similarly, Okorio *et al*. (1994) reported lower height and diameter growth rates of *A. nepalensis* than *A. acuminata* in trials at Kabanyolo and Kachwekano, Uganda, but these authors did not evaluate the *Alnus* species against pest infestations. In this study, provenances Kabale and Chimaltenago had particularly high growth rates, but were the most susceptible to *Septoria* brown leaf spots and insect attacks. This suggests that the *Septoria* disease and insects, especially *A. mellifera*, could be a problem when cultivating *Alnus* from this base population. There is a need to select for resistance within these provenances or another more resistant but fast-growing provenance should be planted to achieve the highest possible yield from *Alnus* trees planted on favourable sites for the pests. Provenance Nepal that showed modest growth rate and absolute resistance to *A. mellifera* seems particularly promising for breeding with the fast-growing, but *A. mellifera* susceptible provenances Kabale and Chimaltenago.

Conclusions and recommendations

This study has demonstrated that *Septoria* leaf spot and insect pests can adversely affect the survival and growth of *Alnus* seedlings in the nursery and the field. Owing to the increasing demand for *Alnus* species in Uganda, appropriate control measures against such pests are needed. Of the provenances evaluated in this study, limited opportunity exists to select for resistance against *Septoria* brown leaf spot. Further studies incorporating new introductions of *Alnus* provenances are needed to determine if genetic resistance against the disease exists in the *Alnus* species. In contrast, there is a wide range of resistance among provenances of *A. acuminata* and *A. nepalensis* against *Apis mellifera* that could contribute to the management of the insect. Overall, there is a need for careful provenance selection in order to maximise the productivity of *Alnus* species in agroforestry.

Acknowledgements

The Norwegian Agency for International Development (NORAD) provided financial support for this research that constituted the principal author's PhD study. We are grateful to ICRAF, Uganda for hosting this study. M. Desales and J. Turyakira provided technical assistance during the fieldwork.

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