Effects of *Acacia auriculiformis* and *Gmelina arborea* on Soil and Microclimate of a Degraded Grassland in Nueva Ecija, Philippines

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Abstract

The effects of *Acacia auriculiformis* aged eight (Aa_8) and two years (Aa_2) old and *Gmelina arborea* eight year-old (Ga_8) stands on the soil and microclimate of degraded grassland in Carranglan, Nueva Ecija, Philippines were studied. Litterfall and leaf litter decomposition under the stands in relation to soil nutrient status and microclimate were evaluated.

The older *A. auriculiformis* stand modified more efficiently the microclimate in terms of reduced air and surface soil temperature, increased relative humidity, and reduced light intensity over the other stands and the open grassland.

Amounts of litterfall were 1,338 and 405.5kg/ha/yr for Aa_8 and Ga_8, respectively. Litter disappearance was fastest in *G. arborea* than in *A. auriculiformis*.

The contents of soil available P, organic matter and total N were most improved under *A. auriculiformis*. However, the contents of exchangeable K, Ca and Mg tended to be temporarily lower due to the more active uptake by the Aa_8 trees. A trend towards soil bulk density improvement over the grassland soil was in the order of $Aa_8 > Aa_2 > Ga_8$.

No initial variations in soil pH were observed. However, burning markedly increased soil pH due to the release of exchangeable K, Ca and Mg from the ash. But pH later declined after the rainy months.

Introduction

Of the thirty million hectares of the total land area of the Philippines, about 41% are marginal lands urgently needing immediate rehabilitation. Some of these areas constitute critical watersheds where adverse climatic, edaphic and biotic conditions hamper the growth and survival of reforestation species.

Reforestation is proposed as a most promising strategy in the rehabilitaion of degraded uplands. However, there is very little information especially in the tropics, on the effects of reforestation on these sites. Basic questions on the effects of species on soil and microclimate, the length of time required before these impacts on the site if ever, are manifested remain largely unanswered.

Literature review

Most studies on forest-microclimate relations dealt with comparisons of forested and cleared areas. Generally, clearing of forest leads to the increase in the air and soil temperature and light intensity and decrease in the relative humidity (Lal and Cummings, 1979; Lawson, 1981). That tree plantations may approximate the radiation budget of forested areas was reported by Monteny, Barbier and Omont (1986) in their study of an intensive rubber plantation.

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Litterfall and leaf litter decomposition studies estimate the rates of nutrient return to the soil. Since the decay of litter is regulated by the nature of the decomposer community, litter resource quality and physico-chemical environment (Swift *et al*., 1979), the rate of nutrient return to the soil is interrelated with species, microclimate and soil conditions.

Lundgren (1978) reported a temporary increase in the amount of soil nutrients after forest clearing and subsequent decline with plantation establishment. In the soils derived from acid rocks, species with acid litter may decrease the amount of soil available nutrients (Allen, 1986). Ohta (1990b) attributed this temporary decrease to active accumultaion in the tree biomass and suggested their probable release as the stand matures. This was based on the observation that the nutrient content of forested areas is remarkably higher than that of degraded grasslands (Ohta, 1990a).

Objectives

The study was conducted to determine the effects of two reforestation species-*Acacia auriculiformis* and *Gmelina arborea* on the soil and microclimate of a marginal grassland area in the Philippines. It also aimed at relating litterfall, stand age and decomposition rate to the microclimate and soil nutrient status under the stands. Because a fire razed parts of the area during the conduct of the experiment, the effects of fire on the soil properties were also detrmined.

Materials and methods

The experiment was conducted in the RP-Japan Reforestation Project Area in Carranglan, Nueva Ecija, Philippines. This area is classified as having a pronounced wet and dry season each year. Mean annual rainfall is 1,800 mm of which about 90% occurs in the months of June to October. The area has a slope of five to 15% and an elevation of 220 to 300m above sea level.

Although the area was initially a dipterocarp forest, deforestation, repeated slash and burn and overgrazing had degenerated it into a grassland dominated by *Themeda triandra*. Other weeds present were *Imperate cylindrica, Saccharum spontaneum, Chromolaena odorata* and *Pennisetum polystachyon*. In the three plantations studied, *T. triandra* was also the dominant grass vegetation.

The soils were previously classified by Yagi (1986a and b) as Ferralitic cambisols or Oxic dystropept. The parent material is rich in sediment of ironstone nodules.

Contiguous stands of *A. auriculiformis* and *G. arborea* and a grassland area were selected. Plots (15m × 15m) were established according to the following treatments, replicated three times:

1 *Acacia auriculiformis*, eight years old (Aa_8)
2 *A. auriculiformis*, two years old (Aa_2)
3 *Gmelina arborea*, eight years old (Ga_8)
4 Grassland (G)

Planting distances were 2.5m × 3.0m for Aa_8, and Aa_2 and 2.5m × 2.0m for Ga_8 stands. Average height taken at the end of the study was 980, 230, 260cm while the diameter at breast height was 15, 3.5 and 5.6cm, respectively for the three stands. The crowns of the Aa_8 stand were almost closed and the forest floor was covered with a thick litter layer (4cm). Litter layer was absent or very thin in the other two stands.

1 Microclimate

Simultaneous hourly observations of the light intensity, air and soil temperatures, and relative humidity were conducted in all the plots on selected days.

2 Litterfall and leaf litter decomposition

Three litter collection traps (1m × 1m) were installed in each of the stands. Litter was collected monthly and the oven-dry weight was determined. Litter decomposition was monitored by measuring the periodic dry weight loss of litterbags left under the stands.

Initial contents of total nitrogen (N), phosphorus (P) and potassium (K) of litter were determined.

3 Soil characteristics

Three composite representative soil samples were collected every two months at a depth of 0-5 cm from each site. These were analyzed for the moisture content, total organic matter (OM), pH, contents of total N, available P and exchangeable K, Ca and Mg using gravimetric, modified Walkley Black, potentiometric, micro-kjeldahl, Bray No. 2, flame photometer and atomic absorption methods, respectively (PCARRD, 1980). Characterization of soil bulk density was also performed using the paraffin clod method.

Results and discussion

1 Microclimate

1) Air temperature

Figure la shows the hourly air temperature in the four sites during a representative day. *G. arborea* consistently showed the highest air temperature followed by the grassland site. Apparently, Ga_8 did not alleviate the high air temperatures occurring in the open area. Lowest air temperatures were recorded in the Aa_8 stand. The most remarkable difference in the air temperature occurred at 1 : 00 pm. In the early morning and late afternoon, the differences in the air temperature among the stands tended to be less pronounced.

2) Light intensity

Hourly light intensity was considerably decreased in the Aa_8 stand. Highest light intensity was observed in the grassland and the more exposed Ga_8 and Aa_2 plots. As in the case of the air temperature a peak in the light intensity was observed at 1 : 00 pm (Fig. lb).

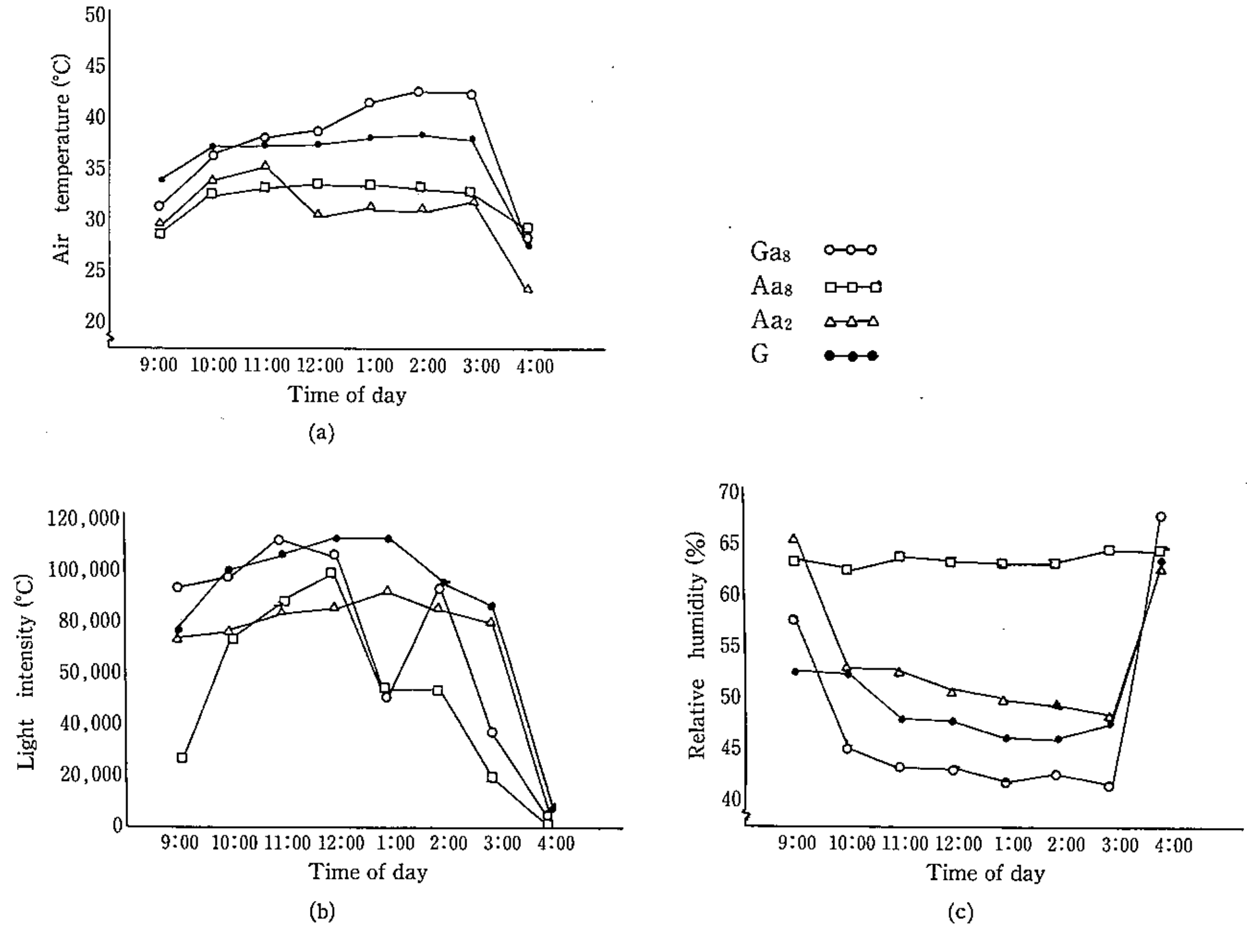


Fig 1 Air temperature (a) relative humidity (b) and average hourly light intensity (c) under different forest stands and in the grassland area.

3) Relative humidity (RH)

Figure. 1c shows the variations in the values of RH in the different plots. RH values were generally higher in the Aa_8 stands, while lowest values occurred in the more exposed Ga_8 and grassland areas.

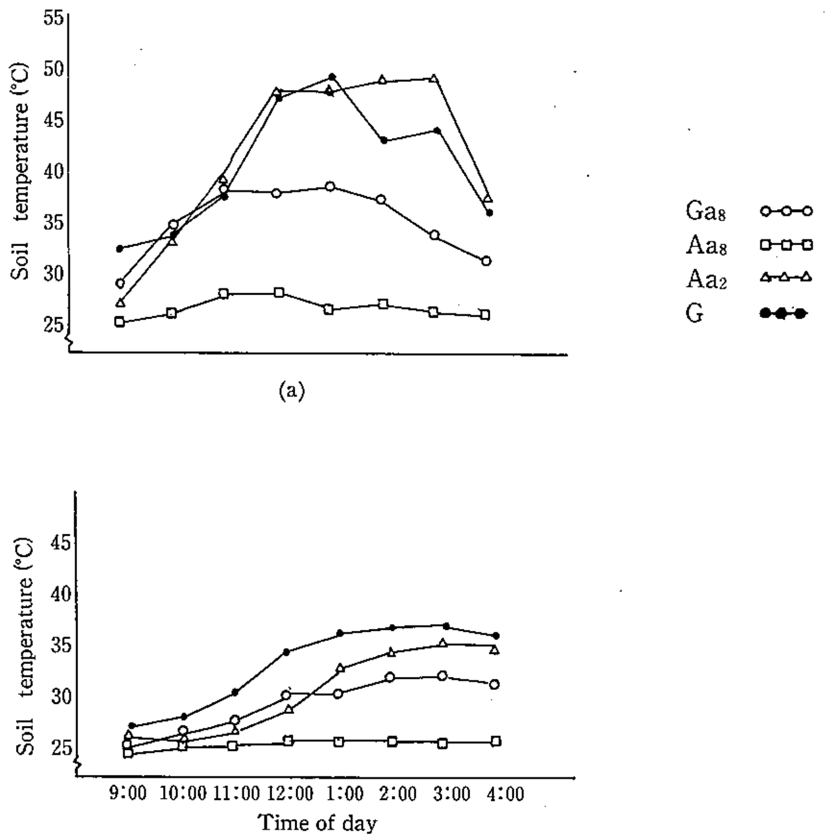
4) Soil temperature

Hourly variations in the soil temperature among the four sites were most pronounced only on the soil surface (Fig. 2a) and at 5 cm (Fig. 2b) depth. The soil temperature was consistently highest in the grassland and Aa_2 sites. It generally decreased with the increase in soil depth. A peak in the surface soil temperature occurred at 1 : 00 pm.

2 Litterfall and leaf litter decomposition

Figure 3a shows the value of mean monthly litterfall in the three stands. Except for the months of January and September, Aa_8 consistently produced the largest amount of litter. In 1990, two peaks in litterfall were observed in Aa_8, occurring in February and May. In 1991, a peak was also observed in February, but a larger amount of litterfall was obtained. In Ga_8, litterfall peaks occurred, in January and September. Total annual litterfall (from February 1990 to January 1991) amounted to 1,338 and 408.5kg/ha for Aa_8 and Ga_8, respectively.

Figure 3b shows that the fastest litter decomposition rate was observed in Ga_8 where there was a 30.62% decrease in the weight of bagged litter after two months, followed by Aa_8 and Aa_2 where the litter weight decreased by 14.0% and 9.11%, respectively. The high values obtained for Ga_8 could be due to the observed activity of termites in this stand. The decomposition rate was faster under the Aa_8 than the Aa_2 stand due to the more favorable microclimate and probably the presence of a more active soil flora and fauna responsible for OM decomposition.



(a)

(b)

Fig. 2 Soil temperature measurements under different forest stands and in the grassland area taken at soil surface (a) and at 5cm depth (b).

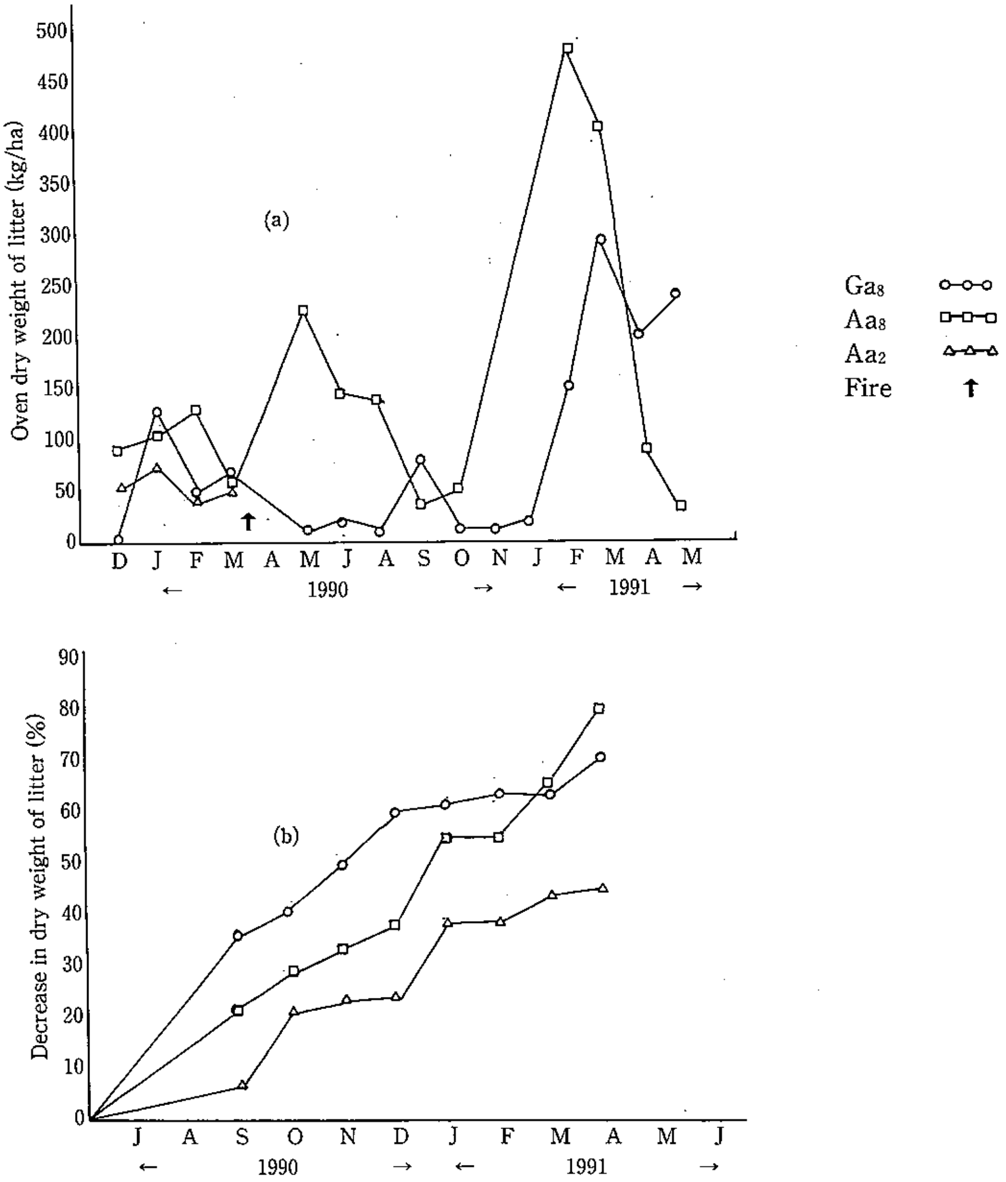


Fig. 3 Monthly dry weight of litterfall (a) and percentage of decrease in dry weight of litter (b) under *A. auriculiformis* and *G. arborea* stands.

3 Soil physical properties

Soil samples collected at the end of the study showed an impovement of the values of bulk densitys. Bulk density (BD) values obtained in the Aa_8, Aa_2, Ga_8 and grassland plots were 1.32, 1.41, 1.52 and 1.56g/cc, respectively. Improvement of the soil bulk density can be attributed to the higher OM content and biological activity of the stand particularly in the *A. auriculiformis* plot. Niijima (1986) reported a higher level of biological activity as evidenced by a richer soil fauna under *A. auriculiformis* than under grassland in Pantabangan. In the present study, it appeared that under the *A. auriculiformis* stand the soil BD was more improved than under the *G. arborea* stand.

Soil moisture contents tended to be improved by the Aa_8 stand during the dry months. The thick litter layer was assumed to reduce evaporation from soil and to increase the moisture retention in the surface soil. Furthermore, the lower air and soil temperatures and higher relative humidity in Aa_8 minimized the soil moisture loss. These influences were absent under Ga_8 where the litter layer was thinner and more easily decomposed.

4 Soil chemical characteristics

1) Soil pH

Figure 4a shows the bimonthly pH values of the soils from the Aa_8, Ga_8 and grassland areas. Initially, fluctuations with no marked variations in the pH values occureed over the months. After a fire razed the area, the pH values of the Aa_8 and Aa_2 soils peaked to 6.5 and 5.7, respectively, above the values for the grassland and unburned Aa_8 plots. This observation can be attributed to the deposition of base-rich ash particularly in the Aa_8 and Aa_2 plots. After eleven months, the effects of fire on the soil pH were no longer evident as heavy rainfall had washed away this ash. The temporary increase in the soil pH after burning is in agreement with numerous reports. Sanchez (1979) observed that burning of tropical forests in the Ultisols and Oxisols in the Amazon increased the soil pH as well as the contents of exchangeable Mg, K and available P.

The unburned Aa_8 plot, generally exhibited the lowest pH values, presumably due to the increased production of organic acids associated with the accelerated organic matter decomposition and the more favorable microclimate in this stand.

2) Organic matter (OM)

Soil organic matter content was generally higher under Aa_8, followed by Ga_8, Aa_2 and the grassland (Fig. 4b). This trend reflected the amount of litterfall in the plantations, absence of litter in the grass-

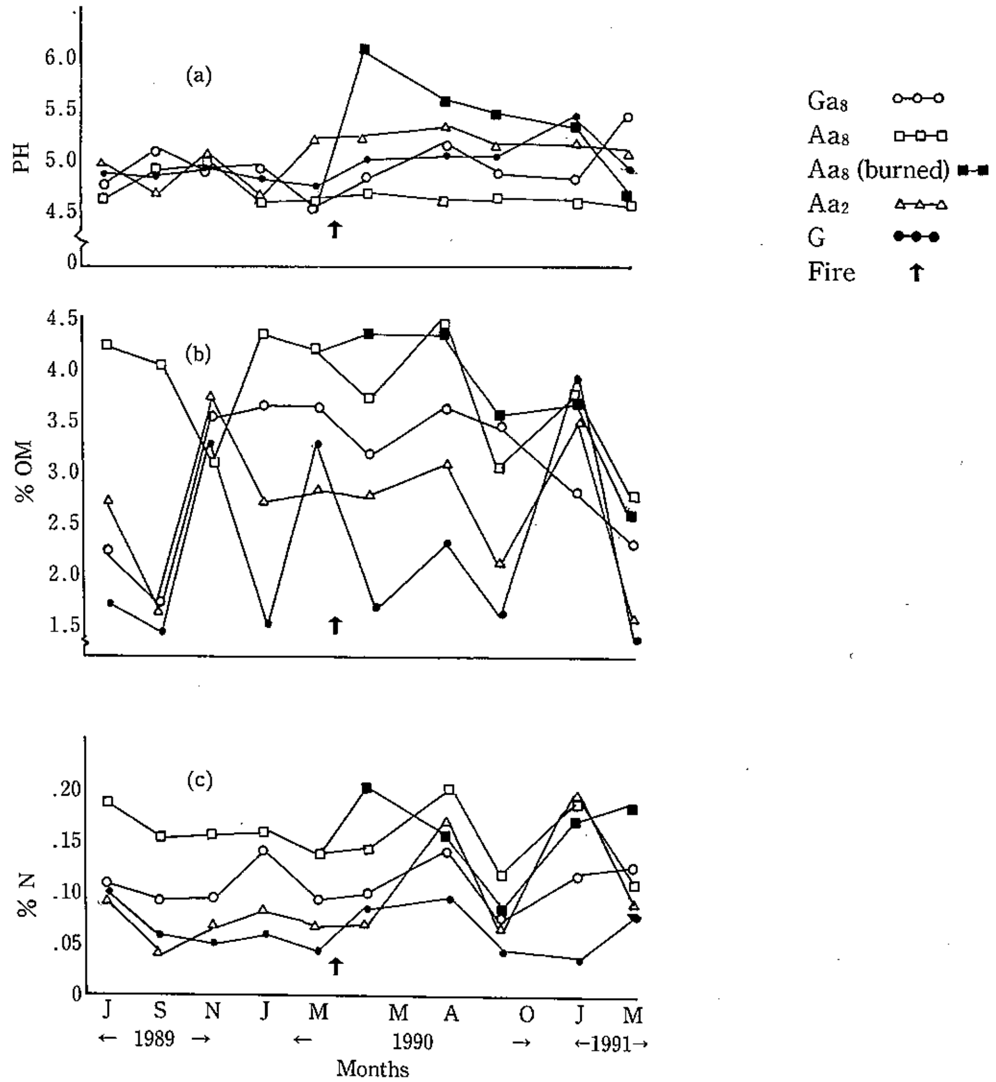


Fig. 4 Bimonthly values of soil pH (a) **organic mattr** (b) **and total nitrogen** (c) **under *A. auriculiformis, G. arborea* stands and in the grassland area at 0-5cm depth.**

land and possibly variations in the activities of soil organisms. The activities of the soil organisms responsible for organic matter decomposition were higher in the forested than in the grassland soils of Pantabangan (Niijima, 1986). Burning of Aa_8 also resulted in a temporary increase of the content of OM due to the deposition of unburned carbon on the soil surface.

3) Total nitrogen

Total N content of the soil (Fig. 4c) was most improved under Aa_8. The Ga_8 and Aa_2 soils also exhibited higher N contents than the grassland soil. The increase in the total N content under Aa_8 was attributed to the large amount of N-rich litter. Furthermore, the improved microclimate conditions were favorable for the activity of N-fixing organisms. Analysis of Aa_8 litter gave a nitrogen value of 1.56%.

At the litterfall rate of 1,338kg/ha/year, the total amount of N added via litterfall in the Aa_8 stand was estimated to be about 20.87kg/ha/year.

4) Available phosphorus

Availability of P (Fig. 5a) was enhanced under Aa_8. In all the sites, the amount of available P in soils showed a peak in January and October in 1990. The enhanced availability of soil P under Aa_8 probably reflected a developed mycorrhizal association which promoted a more efficient P uptake from the P-deficient soil. In acid soils, P availability is limited by the formation of barely soluble P compounds with iron, manganese and aluminum. Mycorrhiza increases the P uptake by the secretion of oxalates which bind to these precipitating cations, thus releasing phosphate ions into the soil solution. As another mechanism, the greater activity of phosphatase enzymes which release organic P into avaliable forms (Binkley, 1986) may be considered. The phosphatase activity has been found to be higher in for-

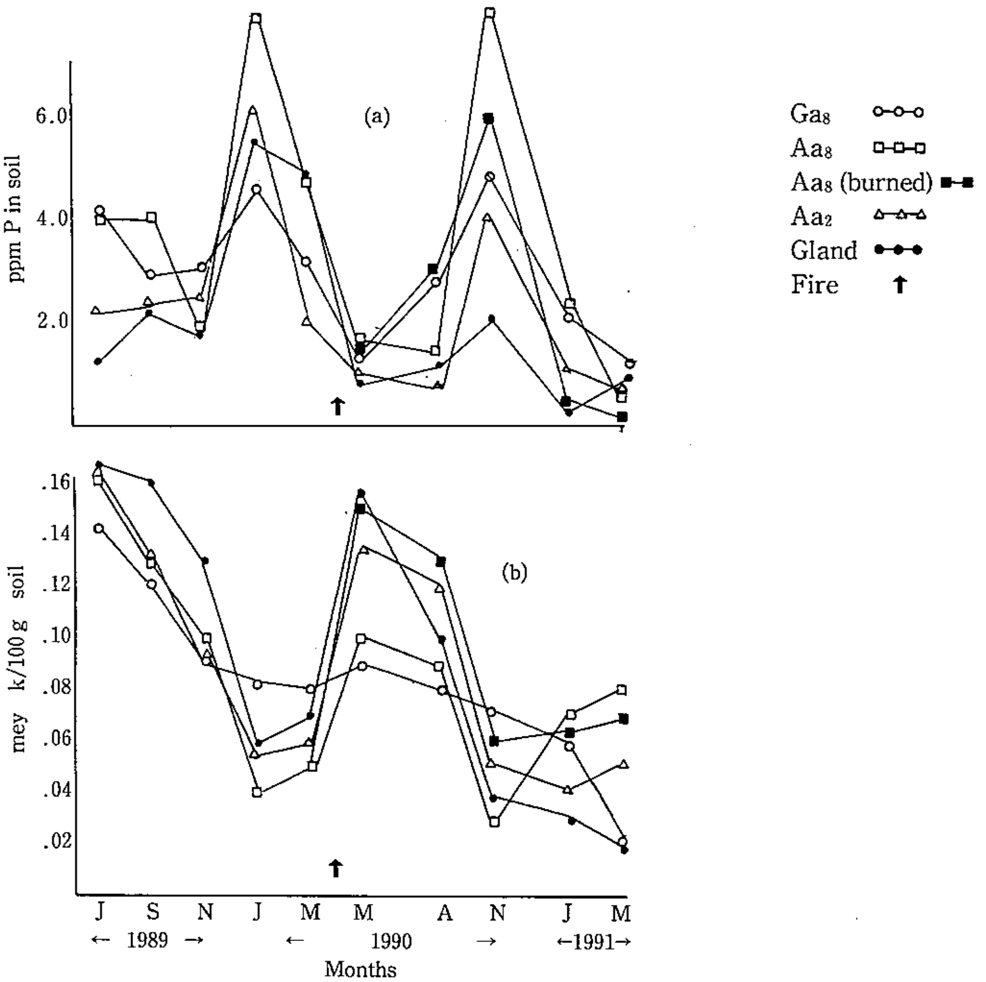


Fig. 5 Bimonthly values of soil available phosphorus (a) and exchangeable potassium (b) under *A. auriculiformis, G. arborea* stands and in the grassland area at 0-5cm depth.

ested than in degraded soils.

Analysis of the litter phosphorus content was 0.18% for both As_8 and Ga_8. Return of P via litterfall was estimated to be 2.41 and 0.73kg p/ha for the Aa_8 and Ga_8 stands, respectively.

5) Exchangeable K, Ca and Mg

The content of soil exchangeable K exhibited seasonal fluctuations in all the sites (Fig. 5b). Burning markedly increased the amount of exchangeable K in the Aa_8, Aa_2 and grassland plots due to the deposition of base-rich ash on the soil surface. The contents of exchangeable Ca and Mg in the soils in the four sites also fluctuated over time. The values were generally lower under Aa_8 and Ga_8 than under Aa_2 and the grassland areas. This decrease in the contents of exchangeable K, Ca and Mg suggests that these compounds are intensively absorbed by the actively growing trees and soil fauna, particularly during the early stages of growth. This trend was also observed by Ohta (1990) who suggested that this phenomenon was temporary, and that the bases would be subsequently released into the soil as the stand matured.

Summary and conclusions

This study showed the effects of the establishment of *A. auriculiformis* and *G. arborea* on the microclimate and the dynamics of nutrients over time compared with the grassland soil.

Establishment of trees, particularly species with deeper crowns and abundant foliage, as in the case of *A. auriculiformis*, ameliorated the microclimate which became stabilized. This microclimate stability was favorable for soil moisture conservation and higher organic matter content due to the larger amount of litterfall. Soil N content significantly increased due to the ability of trees to fix N from the atmosphere. Soil availabe P content increased most by the Aa_8 stand, suggesting an active mycorrhizal association. The decrease in soil K, Ca and Mg availability was observed due to the rapid uptake of the bases by the trees. This condition was expected to be alleviated as the stand matured and these bases were returned to the soil. Older stands of the same species exerted more favorable effects on the soils and microclimate.

The amount of litterfall reflected the effect exerted by the trees on the soil nutrients. Although the disappearance of litter of *G. arborea* was faster than that of the Aa_8 stand, a more active return of nutrients to the soil occurred in *A. auriculiformis* due to its greater bulk and higher nutrient content, particularly N.

This study showed that reforestation of degraded grasslands by fast-growing species like *A. auriculiformis* generally modifies the soil and microclimate. This ability of the stand is closely associated with the litter dynamics, its N-fixing and mycorrhizal symbiosis, and the more stable microclimate in the stands. *G. arborea* tended to modify the soil nutrient conditions but to a lesser extent than *A. auriculiformis*.

It should be recognized, however, that in reforestation programs using multipurpose tree species, it is difficult to reach a more stable nutrient balance and the microclimate characteristic of undisturbed forest ecosystems, largely due to the lower species diversity and stratification that limit the stability of microclimate and soil conditions. Nevertheless, compared with the more adverse conditions of grasslands where the ecological balance and productivity have deteriorated, reforestation offers a ray of hope for the rehabilitation of degraded uplands.

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