Ecology, 92(8), 2011, pp. 1616–1625

Potassium, phosphorus, or nitrogen limit root allocation, tree growth, or litter production in a lowland tropical forest

S. Joseph Wright,[1,10] Joseph B. Yavitt,[2] Nina Wurzburger,[1,3] Benjamin L. Turner,[1] Edmund V. J. Tanner,[4] Emma J. Sayer,[5] Louis S. Santiago,[6] Michael Kaspari,[1,7] Lars O. Hedin,[3] Kyle E. Harms,[1,8] Milton N. Garcia,[1] and Marife D. Corre[9]

[1]*Smithsonian Tropical Research Institute, Apartado 0843-03092, Balboa, Republic of Panama*
[2]*Department of Natural Resources, Cornell University, Ithaca, New York 14853 USA*
[3]*Department of Ecology and Evolutionary Biology, Princeton University, Princeton, New Jersey 08540 USA*
[4]*Department of Plant Sciences, University of Cambridge, Cambridge CB2 3EA United Kingdom*
[5]*Centre for Ecology and Hydrology, Benson Lane, Crowmarsh Gifford, Wallingford OX10 8BB United Kingdom*
[6]*Department of Botany and Plant Sciences, University of California, Riverside, California 92521 USA*
[7]*Department of Zoology, University of Oklahoma, Norman, Oklahoma 73019-0235 USA*
[8]*Department of Biological Sciences, Louisiana State University, Baton Rouge, Louisiana 70803 USA*
[9]*Soil Science, Büsgen Institute, Georg-August-University Göttingen, Büsgenweg 2, 37077 Göttingen, Germany*

Abstract. We maintained a factorial nitrogen (N), phosphorus (P), and potassium (K) addition experiment for 11 years in a humid lowland forest growing on a relatively fertile soil in Panama to evaluate potential nutrient limitation of tree growth rates, fine-litter production, and fine-root biomass. We replicated the eight factorial treatments four times using 32 plots of 40×40 m each. The addition of K was associated with significant decreases in stand-level fine-root biomass and, in a companion study of seedlings, decreases in allocation to roots and increases in height growth rates. The addition of K and N together was associated with significant increases in growth rates of saplings and poles (1–10 cm in diameter at breast height) and a further marginally significant decrease in stand-level fine-root biomass. The addition of P was associated with a marginally significant ($P = 0.058$) increase in fine-litter production that was consistent across all litter fractions. Our experiment provides evidence that N, P, and K all limit forest plants growing on a relatively fertile soil in the lowland tropics, with the strongest evidence for limitation by K among seedlings, saplings, and poles.

Key words: Barro Colorado Nature Monument, Panama; fertilization; fine litter; fine roots; nitrogen; nutrient limitation; phosphorus; potassium; tree growth; tropics.

Introduction

Fertilizers that combine nitrogen (N), phosphorus (P), and potassium (K) are routinely required to maintain agricultural productivity. The role of nutrient limitation is less certain in natural ecosystems for at least two reasons. First, nutrients are recycled through decomposition rather than being removed in harvests. Second, most wild plants tolerate lower nutrient supplies than do most agricultural species. In natural ecosystems, nutrients are supplied by weathering rock, atmospheric deposition, and, in the case of N, biological fixation. All ecosystems lose nutrients through gaseous emission, leaching to groundwater, and overland export to streams and rivers. The potential for nutrient limitation in wild plants reflects the ability of plants to adjust to the local balance of nutrient supply and loss.

The balance of nutrient supply and loss changes as soils age and, in the case of N, with latitude (Walker and Syers 1976, Vitousek 1984, Vitousek and Sanford 1986, Hedin et al. 2009, Vitousek et al. 2010). Weathering bedrock is the primary source of P and K, and their availability tends to decline as soils age (Walker and Syers 1976, Hedin et al. 2003). In regions of active geological uplift, ongoing erosion continues to supply rock-derived nutrients (Porder et al. 2007). Elsewhere as soils age, long-distance transport in dust and precipitation becomes the principal source of rock-derived nutrients. In contrast, N is largely absent from igneous and metamorphic rock, its primary sources are biological fixation and atmospheric deposition, and its supply initially increases in young soils, reaches maximum levels in moderately weathered soils, and declines in some highly weathered soils as other nutrients come to limit biological N fixation (Vitousek 2004, Lambers et al. 2008, Barron et al. 2009). Some lowland tropical forests sustain levels of N cycling, N losses, N:P ratios in leaves and fine litter, and C:P ratios in fine litter that far exceed levels observed in temperate and boreal forests (Vitousek 1984, McGroddy et al. 2004). A latitudinal gradient in soil age contributes to this trend, with lower N and greater P availability on younger soils initiated by repeated glacial cycles and the widespread deposition of

Manuscript received 6 August 2010; revised 21 January 2011; accepted 22 February 2011. Corresponding Editor: L. A. Donovan.
[10] E-mail: wrightj@si.edu

glacial dust at higher latitudes (Vitousek and Sanford 1986). In addition, N fixation by heterotrophic bacteria and epiphytes that are decoupled from soil N supplies and up-regulation of biological N fixation by abundant legumes should disturbance reduce N availability are hypothesized to sustain high N losses from N-rich tropical forests (Hedin et al. 2009). For these reasons, supplies of N, P, and K are all likely to be relatively high in N-rich, lowland tropical forests growing in regions of active geological uplift.

Plants adjust to local nutrient availability through changes in species composition, phenotypic plasticity, and adaptation. As an example of changes in species composition, tree species characterized by dense wood and low foliar nutrient concentrations dominate forests on nutrient-poor soils in the geologically stable eastern and central Amazon and tend to be replaced by tree species characterized by lighter wood and larger foliar nutrient concentrations on richer soils influenced by the rapidly eroding Andes in the western Amazon (Fyllas et al. 2009, Patiño et al. 2009). As an example of a likely mix of phenotypic plasticity and local adaptation, widespread Amazonian species tend to have denser wood and lower foliar nutrient concentrations when growing on poorer soils (Fyllas et al. 2009, Patiño et al. 2009). Collectively, these adjustments mediate the potential limitation of primary production by nutrients and are likely to lead to simultaneous limitation by multiple nutrients. Simultaneous limitation can arise through physiological responses that maintain homeostasis at the level of individual plants, limitation of different species by different nutrients at the level of plant communities, and positive feedbacks among nutrient supply rates at the level of ecosystems (Vitousek et al. 2010).

Recent meta-analyses of fertilization experiments are broadly consistent with the hypothesis that multiple nutrients limit plant growth in natural communities. A meta-analysis of 38 potassium fertilization experiments involving 26 forest tree species demonstrates that K addition tends to increase growth rates (69% of studies) and tissue K concentrations (76%; Tripler et al. 2006). A meta-analysis of 126 terrestrial N fertilization experiments demonstrates that N is equally likely to limit aboveground net primary production at all latitudes (LeBauer and Treseder 2008). Finally, a meta-analysis of 173 terrestrial studies that included independent manipulations of N and P or factorial manipulation of N and P demonstrates that N and P tend to co-limit plant biomass or plant productivity (Elser et al. 2007).

Unfortunately, lowland tropical forests are underrepresented in these meta-analyses. There has not been a single K fertilization experiment in a tropical forest. Just five P fertilization experiments and four N fertilization experiments have evaluated community-level responses in lowland tropical forests. Most of these experiments took place in young secondary forests, where reduced organic matter pools limit nutrient availability and rapid increases in plant biomass sustain high nutrient demand (Campo and Vazquez-Yanes 2004, Davidson et al. 2004). The only fertilization experiments conducted in old-growth, lowland tropical forests are a four-year factorial manipulation of N and P on a relatively infertile soil in Borneo (Mirmanto et al. 1999) and a two-year manipulation of P on a relatively infertile soil in Cameroon (Newbery et al. 2002). We lack a single fertilization experiment that has lasted more than four years in a lowland tropical forest.

For these reasons, we initiated a chronic NPK factorial fertilization experiment in an old-growth tropical forest in the lowlands of Panama in 1998. Here, we report the first 10 to 11 years of responses for fine-root biomass, fine-litter production, and tree growth rates. We evaluate radial growth responses of saplings, poles, and larger trees separately because they experience contrasting light levels, and light availability is likely to limit potential responses to fertilization in shaded plants. We expected the strongest responses for P and K addition in this N-rich forest and for progressively larger trees that experience progressively higher light levels.

Methods

Study site

The 38.4-ha study site (9°06′31″ N, 79°50′37″ W) is located on the mainland in the Barro Colorado Nature Monument in the Republic of Panama (Appendix A: Fig. A1). Tree species composition and stature (canopy heights up to 40 m) are characteristic of very old (>200 yr), secondary forest. Aerial photographs confirm the presence of tall forest at the site in 1927 (S. J. Wright, *personal observation*).

Table 1 summarizes concentrations of N, P, and K in bedrock and fine litter and in plant available forms in surface soils (0–10 cm depth) in our control plots. The bedrock is an 85-m thick Miocene basalt (Stewart et al. 1980) and is relatively rich in P (Table 1). Elevation grades from 25 m in the southwest to 61 m in the northeast corner of the study site (Appendix A: Fig. A1). In the FAO classification, the soils are Endogleyic Cambisols and Acric Nitisols in the lower and upper parts of the landscape, respectively (Koehler et al. 2009, who accidentally reverse the position of the soil types). These soil types are widespread in Mesoamerica (IUSS Working Group WRB 2006). Plant available soil nutrient concentrations are representative of forest soils in central Panama (B. L. Turner, *unpublished data*), and soil K concentrations are representative of Mesoamerica (Barthold et al. 2008). Total P and total reserve base concentrations are 600 mg/kg and 97 $mmol_c/kg$, respectively, for the upper 30 cm of soil (J. B. Yavitt, *unpublished data*). Total P and reserve base concentrations are smaller for >92% and 60% of 63 Amazonian sites (Fyllas et al. 2009), respectively. Soils at the study site are relatively fertile for the lowland tropics.

TABLE 1. Nutrient status in bedrock, fine litter, and surface soils of the study site in the Barro Colorado Nature Monument, Panama.

Element	Bedrock (ppm)†	Input in litter ($kg \cdot ha^{-1} \cdot yr^{-1}$)‡	Concentration in control soils (mg element/kg dry soil)§
K	3410	57	84–131
N		180	5.3–5.6 nitrate; 6.2–15.5 ammonium
P	1600	11	1.4–2.2

† Mean value for Miocene basalts in the Panama Canal area (C. Jaramillo, *unpublished data*).
‡ Measured for forest 3 km from our site on Barro Colorado Island (Yavitt et al. 2004).
§ For samples stored at 2–4°C for 24–48 h and extracted in 2 mol/L KCl for ammonium and nitrate, Mehlich III for the smaller K and P values, Bray 1 for the larger P value, and 1 mol/L NH_4Cl for the larger K value (Yavitt et al. 2009, Sayer and Tanner 2010).

Experimental design

We replicated the eight treatments of a 2 × 2 × 2 factorial NPK experiment four times. We placed the four replicates perpendicular to the 36-m topographic gradient because soil properties (Yavitt et al. 2009) and tree distributions (S. J. Wright, *unpublished data*) parallel the gradient. Within each replicate, we blocked the N, P, K, and NPK treatments vs. the NP, NK, PK, and control treatments (Appendix A: Fig. A1). This balanced, incomplete-block design minimizes uncontrolled error associated with spatial variation, enables evaluation of main effects and two-way interactions, but limits power to evaluate the three-way interaction (Winer 1971). The 32 experimental plots each measured 40 × 40 m. The minimum distance between plots was 40 m, excepting two plots separated by 20 m and a 3 m deep streambed (Appendix A: Fig. A1).

Beginning in 1998, we added fertilizer by hand in four equal doses each wet season with 6–8 weeks between applications (15–30 May, 1–15 July, 1–15 September, and 15–30 October). Nitrogen was added as coated urea ($(NH_2)_2CO$), P as triple superphosphate ($Ca(H_2PO_4)_2.H_2O$), and K as potassium chloride (KCl). Annual doses were 125 kg $N \cdot ha^{-1} \cdot yr^{-1}$, 50 kg $P \cdot ha^{-1} \cdot yr^{-1}$, and 50 kg $K \cdot ha^{-1} \cdot yr^{-1}$, which equals 69%, 470%, and 88% of annual inputs from fine litter at a nearby site (3 km), respectively (Table 1). Similar large additions of P relative to annual litter inputs are standard practice in forestry and in previous tropical nutrient addition experiments (Tanner et al. 1992, Mirmanto et al. 1999, Fisher and Binkley 2000) because many soils, including soils at our site, sequester large amounts of added P in forms that are inaccessible to plants (Yavitt et al. 2010). After nine years, N addition had reduced soil pH and base saturation and increased nitrate leaching, N-oxide emissions, and aluminum saturation (Corre et al. 2010).

Tree growth

We measured diameter at breast height (dbh) or just above buttresses for all free-standing woody plants with dbh > 10 cm in the central 30 × 30 m and with dbh ≥ 1 cm in the central 20 × 30 m of each 40 × 40 m plot in 1997, 2000, and 2008 (see Plate 1). All measured trees were > 5 m from the nearest plot boundary. For analyses of relative growth rates (RGR), we excluded trees with multiple stems, broken stems, and buttresses or other deformities whose growth prevented measurements at the same height in consecutive censuses. The 9551 trees that remained included those that first recruited to the 1-cm dbh minimum size threshold and those that died between 2000 and 2008. We calculated RGR for 1997–2000 and 2000–2008 as $RGR_{i\text{–}f} = \log(dbh_f/dbh_i)/((DC_f - DC_i)/365)$, where DC represents day of century and the subscripts *i* and *f* represent initial and final values, respectively. We performed separate analyses for four tree size classes (1.0 cm ≤ dbh ≤ 2.4 cm, 2.5 cm ≤ dbh ≤ 4.9 cm, 5.0 cm ≤ dbh ≤ 9.9 cm, and dbh ≥ 10 cm) to isolate trees with contrasting levels of shading and to control size-related variation in RGR. Response variables were mean RGR for each plot, census interval, and size class. The median (minimum) number of trees used to calculate RGR for each plot and census interval was 75 (36), 47 (19), 23 (10), and 19 (7) for the smallest to largest size classes, respectively.

Fine-root biomass

We collected soil to 10 cm depth from four (six in 2009) random locations in the central 20 × 20 m of each plot with a 5 cm diameter split-sleeve core in April 2000, November 2008, and April 2009. We washed soils through a 0.5-mm sieve leaving roots and coarse sand. We oven-dried fine (<2 mm diameter) and coarse (2–5 mm) roots to constant mass at 60°C. We performed separate analyses for 0–5 and 5–10 cm depths and for fine roots only because many cores lacked coarse roots. Response variables were mean dry mass for each plot, year, and depth.

Fine-litter production

We randomly located three litter traps in the central 30 × 30 m of each plot on 1 July 1998. The minimum distance between traps was 10 m. Each trap had an effective surface area of 0.58 m^2 composed of an open bag of 1-mm mesh window screen raised 80 cm above the ground on a PVC frame. We collected litter once each month following the methods of Proctor (1983), oven-dried litter to constant mass at 60°C, and, beginning in November 1998, weighed leaves, wood, reproductive material, and other fine litter or "dust"

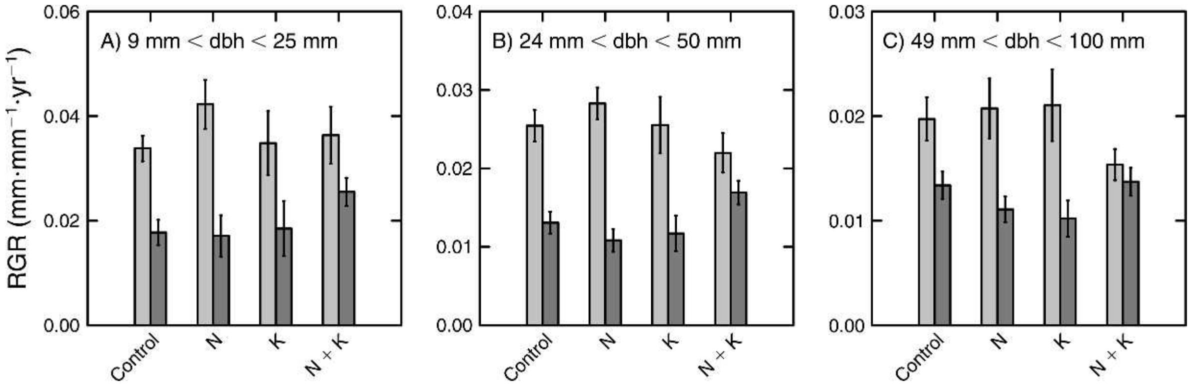

Fig. 1. Tree growth responses to nitrogen (N) and potassium (K) addition for three subcanopy size classes. Each panel illustrates a significant N × K × census interaction ($F_{1,18} = 5.45$, 8.34, and 6.82; $P = 0.031$, 0.010, and 0.018 in panels (A), (B), and (C), respectively). Relative growth rates (RGR) declined significantly from 1997–2000 (light bars) to 2000–2008 (dark bars) for each size class. N plus K addition ameliorated the decline for all three size classes. The full experiment included eight factorial N, K, and phosphorus (P) treatments. P addition had no significant effects on RGR, and the four P addition treatments (P, N + P, K + P, and N + K + P) are pooled with the appropriate treatment without P (control, N, K, and N + K, respectively). Thus, bars represent RGR (mean ± SE) for eight plots. Above each panel are the diameter at breast height (dbh) limits for the tree size class.

separately. The response variable was mean dry mass production ($Mg \cdot ha^{-1} \cdot yr^{-1}$) for each plot and year. Years extended from 1 November to 31 October.

Aboveground net primary production (ANPP)

We summed fine-litter and wood production to estimate ANPP. To estimate wood production, we estimated the aboveground biomass (AGB) of each tree at each census (1997, 2000, and 2008) using its dbh, wood density (g dry mass/cm^3 fresh volume) determined for each species (Wright et al. 2010), and the "best predictive equation" for tropical moist forest from Chave et al. (2005). Mean wood density was substituted for six rare species that lacked a wood density measurement. Stand-level wood production equaled the sum of AGB_f–AGB_i for trees that survived from census i to census f and the AGB of trees that recruited during the census interval. The response variable was dry mass production of wood plus fine litter ($Mg \cdot ha^{-1} \cdot yr^{-1}$) for each plot and year.

Analyses

We performed repeated-measures analyses of variance (ANOVA) for each response variable to control spatial variation among plots and to evaluate temporal variation. Between-subject (henceforth, between-plot) effects evaluate responses over the entire experiment. Within-subject (henceforth, within-plot) effects evaluate variation among years and interactions among treatments and year. A nutrient response that lagged behind the initial addition of nutrients might be insignificant over the entire experiment but lead to a significant treatment × year interaction. Such lags characterize tree responses to fertilization (Tanner et al. 1992). Repeated-measures ANOVA assumes compound symmetry of the variance–covariance matrix if there are more than two repeated measures. We therefore used the conservative Greenhouse-Geisser correction for violations of the compound symmetry assumption to evaluate the significance of all within-plot effects for fine-root biomass and fine-litter production, which had three and 11 repeated measures, respectively. All analyses were performed with SYSTAT 11.0 (Richmond, Calfornia, USA).

Results

Tree growth

Tree growth rates decreased through time (Figs. 1 and 2). $RGR_{2000–2008}$ was significantly smaller than $RGR_{1997–2000}$ for all four tree size classes ($F_{1,18} > 15.0$, $P < 0.001$; Appendix B: Tables B1–B4).

A single consistent response to nutrient addition characterized the three smaller size classes (Fig. 1). The N × K × year interaction was significant for each of these size classes ($F_{1,18} = 6.82$, 8.34, and 5.45; $P = 0.018$, 0.010, and 0.031; Appendix B: Tables B2, B3, and B4, respectively). The combined N + K treatment ameliorated the temporal decline in RGR. The pattern of similar growth rates for control, N, K, and combined N + K treatments in the first interval and larger growth rates for the combined N + K treatment in the second interval indicates a positive lagged response to the combined N + K treatment (Fig. 1).

The response of large trees (dbh > 10 cm) to nutrient addition was more complicated (Fig. 2; Appendix B: Table B1). The between-plot, N × K interaction was marginally significant (Appendix B: Table B1; $F_{1,18} = 4.41$, $P = 0.050$) because RGR was similar for the control and combined N + K treatments but larger for the N and K treatments (Fig. 2B).

The P × year interaction was also significant for large trees (Fig. 2C; $F_{1,18} = 7.95$, $P = 0.011$; Appendix B: Table B1); however, the pattern of growth rates underlying this interaction is inconsistent with a positive response to P addition. Added P appears to have depressed

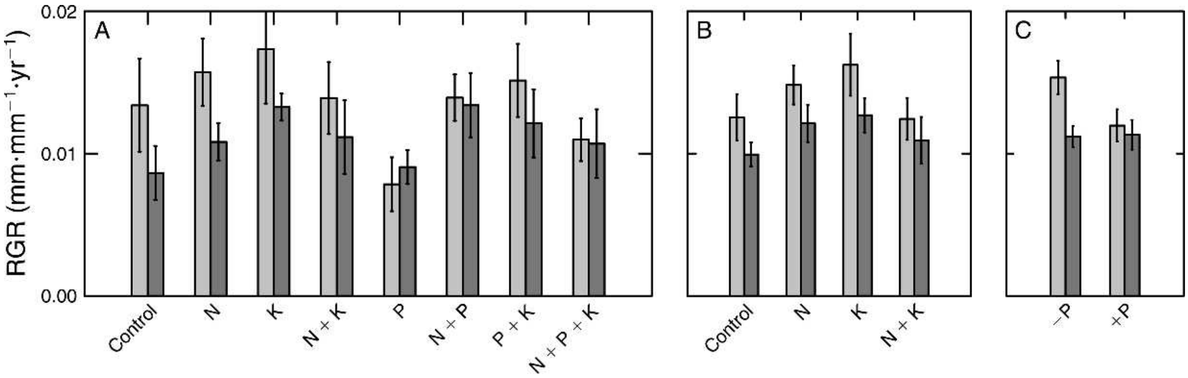

FIG. 2. Growth responses of large trees (>10 cm dbh) to phosphorus (P), nitrogen (N), and potassium (K) addition. Relative growth rates (RGR) declined significantly from 1997–2000 (light bars) to 2000–2008 (dark bars). Panel (A) presents the eight treatments in the full factorial NPK design, and bars represent RGR (mean ± SE) for four plots. Panel (B) presents the marginally significant N × K interaction ($F_{1,18} = 4.41$, $P = 0.050$). The P addition treatments (P, N + P, K + P, and N + K + P) are pooled with the appropriate treatment without P (control, N, K, and N + K, respectively), and bars represent RGR (mean ± SE) for eight plots. Panel (C) presents the significant P × census interaction ($F_{1,18} = 7.95$, $P = 0.011$). The four P addition treatments (P, N + P, K + P, and N + K + P) are pooled, the four treatments without P (control, N, K, and N + K) are pooled, and bars represent RGR (mean ± SE) for 16 plots.

$RGR_{1997–2000}$ and to have had no effect on $RGR_{2000–2008}$ (Fig. 2C). The arrangement of treatments in Fig. 2A also illustrates the effect of added P. The control, N, K, and combined N + K treatments are arranged from left to right first without and then with added P (Fig. 2A). Added P did not increase tree growth rates.

Fine-root biomass

Fine-root biomass in surface soils (0–5 cm depth) varied significantly with K addition. The addition of K was associated with a significant reduction in fine-root biomass (Fig. 3A; $F_{1,18} = 9.69$, $P = 0.006$; Appendix B: Table B5). The N × K × year interaction was also marginally significant ($F_{2,36} = 3.22$, $P = 0.064$; Appendix B: Table B5), with fine-root biomass in surface soils reduced in one year with N addition alone, in two years with K addition alone, and in all three years with combined NK addition (Fig. 3B). Fine-root biomass in subsurface soils (5–10 cm depth) was unaffected by nutrient additions (Appendix B: Table B6).

Fine-root biomass also varied significantly among years. Fine-root biomass was approximately twice as large in April 2000 as in November 2008 and April 2009 (Fig. 3B; Appendix B: Tables B5 and B6). Similar large temporal variation in fine-root biomass has been observed previously in a nearby forest (Cavelier et al. 1999).

Fine-litter production

There was a marginally significant increase in fine-litter production with P addition (Fig. 4A; $F_{10,180} = 4.10$, $P = 0.058$; Appendix B: Table B7).We also examined the four fractions that comprise fine-litter production separately (Fig. 4B–E). The mean level of production was larger where P was added and smaller where P was not added for 39 of the 44 combinations of year and litter fraction (Fig. 4B–E). Two of the five exceptions were for the first year of the experiment (Fig. 4D–E). The three remaining exceptions were for reproductive structures (Fig. 4C). Reproductive output varies widely in space and time in central Panama (Wright et al. 2005). As an example, the coefficient of variation (SD/mean) of annual production (averaged over the 32 experimental plots) was 250% to 500% greater for reproductive structures (0.203) than for total fine litter (0.040), leaf litter (0.055), or small branches (0.080). It is not surprising that the spatial and temporal variation in reproductive output sometimes overwhelmed the effect of added P. The consistent increase in the three remaining fractions of fine-litter production after the first year of P addition (30 out of 30; Fig. 4B, D, and E) suggests that the marginally significant effect of P addition on total fine-litter production is real.

Aboveground net primary production (ANPP)

ANPP averaged 14.7 ± 4.0 Mg·ha^{-1}·yr^{-1} (mean ± SD). This included 11.4 ± 3.2 and 4.2 ± 2.7 Mg·ha^{-1}·yr^{-1}of fine-litter and wood production, respectively. There were no significant effects of nutrient treatments for ANPP (Appendix B: Table B8); however, we have little confidence in our plot-level estimates of wood production and hence ANPP. Our plot-level estimates of wood production were highly variable. As an example, the overall coefficient of variation (SD/mean) for plots was 0.64 and 0.28 for wood and fine-litter production, respectively. We believe our plots are too small to estimate wood production accurately because just 3% of the trees larger than 10 cm dbh account for 50% of the aboveground biomass (Muller-Landau et al. 2006) and a similar percentage of wood production in mature forests in central Panama. Our effective plot size was just 0.09 ha because trees were not

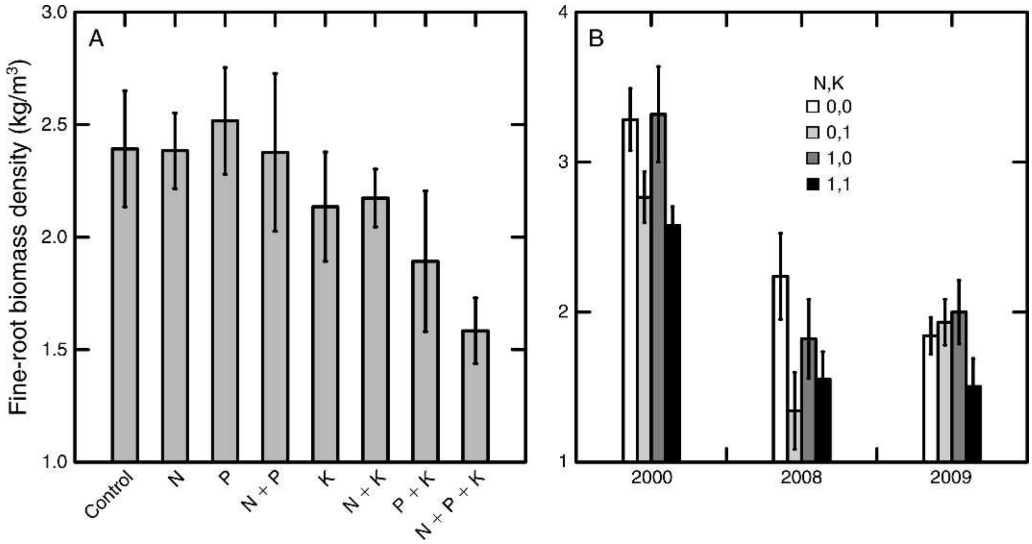

FIG. 3. Fine-root biomass responses to nutrient addition for surface soils (0–5 cm depth). Panel (A) presents the eight treatments in the factorial NPK design. The four treatments with K addition are to the right to illustrate the significant effect of K addition ($F_{1,18} = 9.69$, $P = 0.006$). Bars represent values (mean ± SE) for four plots and three years. Panel (B) isolates the marginally significant N × K × year interaction ($F_{2,36} = 3.22$, $P = 0.064$). The inset key matches the shading of the bars with the four factorial combinations of N and K, where 1's and 0's represent plots where N or K were added or not added, respectively. P addition had no significant effects on fine-root biomass, and the four P addition treatments (P, N + P, K + P, and N + K + P) are pooled with the appropriate treatment without P (control, N, K, and N + K, respectively). Bars represent values (mean ± SE) for eight plots in panel (B).

measured in a 5-m fertilized buffer. A plot of 0.09 ha might or might not contain a large tree, and this ensured highly variable plot-level estimates of wood production. We do not mention ANPP again.

DISCUSSION

The addition of N, P, and K increased concentrations of the same nutrient in soils, leaves, and fine litter in an old-growth, lowland tropical forest growing on a relatively fertile soil in Panama (Table 2). Experimental increases in tissue concentrations might represent luxury consumption or might enable additional plant responses if nutrients limit plant function. We evaluated community-level responses to nutrient addition including fine-root biomass, fine-litter production, and tree growth rates.

Relative growth rates (RGR) declined significantly during the 11-year study (Figs. 1 and 2; Appendix B: Tables B1–B4). This is the fourth tropical forest for which a decadal trend toward slower tree growth rates has been observed (Feeley et al. 2007, Clark et al. 2010). Possible mechanisms include rising temperatures and temperature-dependent respiration rates and/or temperature-dependent photosynthetic rates, increasing abundance of competing woody vines, increasing competition among trees in the final stages of secondary succession, natural decadal climate variation, and cumulative effects of trampling (Wright 2010). Regardless of its cause, slowing tree growth rates affect the interpretation of responses to nutrient addition. A positive response to nutrient addition that lags behind the initial application of nutrients might be expressed as a relatively small decline in RGR and not as an increase in RGR. We performed repeated-measures analyses with repeated measures on census intervals to evaluate temporal variation in each response variable and possible lagged responses to nutrient addition.

Responses to phosphorus addition

It is widely hypothesized that P limits primary production on highly weathered tropical soils (see *Introduction*; Vitousek 1984, Lambers et al. 2008, Hedin et al. 2009). Six P fertilization experiments have now been conducted in lowland tropical forests. Three of the six took place in young secondary forests (Campo and Vazquez-Yanes 2004, Davidson et al. 2004), where relatively small organic matter pools limit nutrient availability, rapid biomass accumulation provides a strong nutrient sink, and nutrient limitation is to be expected regardless of soil weathering status. Not surprisingly, tree growth rates and/or fine-litter production increased after 3–4 years of P addition in these 4-, 12-, and 60-year-old secondary forests (Campo and Vazquez-Yanes 2004, Davidson et al. 2004).

The three remaining P addition experiments took place in old-growth forests and provide an opportunity to evaluate the hypothesis that P limits tree growth and fine-litter production in mature lowland, tropical forests. The three experiments took place on soils with total P concentrations of 80 mg P/kg (upper 10 cm; Mirmanto et al. 1999), 277 mg P/kg (average of upper 5 cm and 15–20 cm; Newbery et al. 2002), and 484 mg P/kg (upper 15

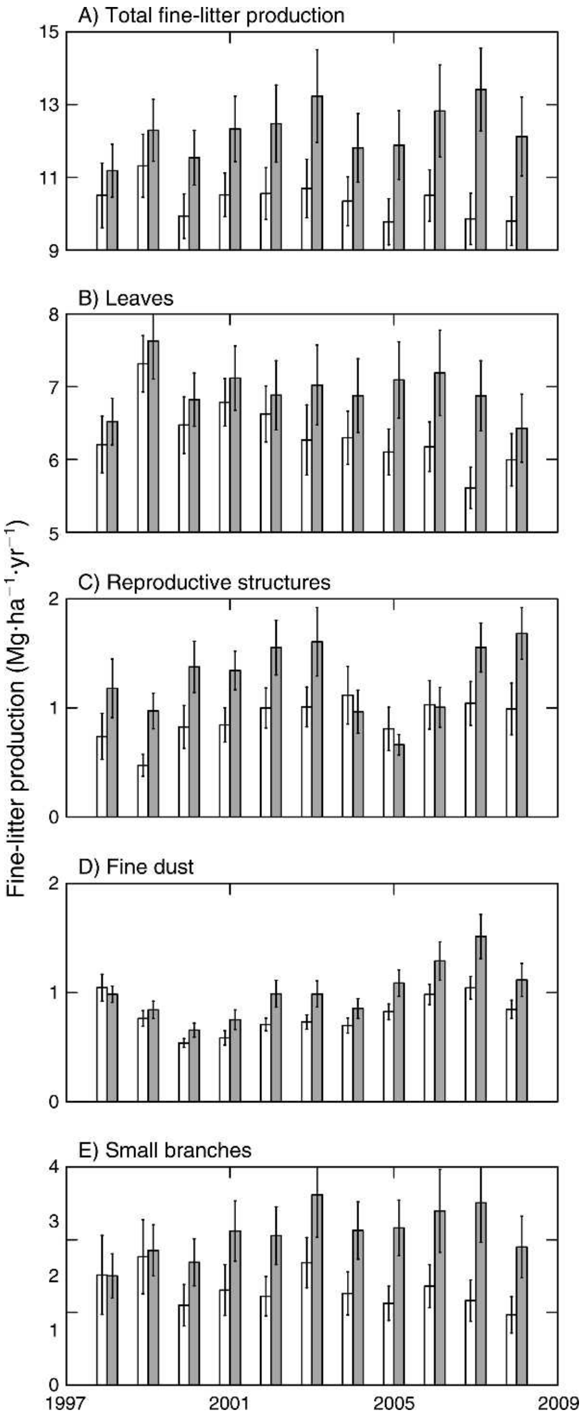

FIG. 4. Responses to phosphorus (P) addition for total fine-litter production (panel A, $F_{1,18} = 4.10$, $P = 0.058$) and its four fractions (panels B–E) over 11 years. Solid and open bars represent pooled treatments with and without added P, respectively. The four litter fractions are (B) leaves, (C) reproductive structures, (D) fine material or dust, and (E) twigs and small branches. The addition of N and K had no significant effects. Therefore, the four P addition treatments (P, N + P, K + P, and N + K + P) are pooled, the four treatments without P (control, N, K, and N + K) are pooled, and each bar represents production (mean ± SE) for 16 plots.

cm, see *Results*; Yavitt et al. 2010). P addition had no significant effect on tree growth at any of these sites. At the low-P site, fine-litter production averaged 25% greater with P addition than in controls just 8–20 months after the first P application (Mirmanto et al. 1999). At the intermediate-P site, there was no significant effect on fine-litter production; however, fine litter was measured for just one month ~2.5 years after the initial P application and 0.5 years after the final P application (Newbery et al. 2002). Finally at our high-P site, fine-litter production averaged 25% greater with P addition than in controls for years eight through 11 after the first P application (Fig. 4A). The obvious conclusion is that more and longer P fertilization experiments will be required before generalization is possible. In the meantime, the evidence that P limits fine-litter production at a P-poor site in Borneo and a relatively P-rich site in Panama suggests that P is likely to limit plant production in many tropical forests.

Responses to nitrogen addition

It is widely hypothesized that N is available in excess of plant demand in lowland tropical forest soils (see *Introduction*; Vitousek 1984, Hedin et al. 2009). LeBauer and Treseder (2008) rejected this hypothesis and concluded that N limitation was equally strong for temperate and tropical forests. Their conclusion is based on a meta-analysis of N addition experiments that included 15 tropical forest experiments; however, just four of these 15 experiments took place in the lowlands. The remaining 11 experiments took place in montane forests. The N cycles and C:N ratios of fine litter in montane tropical forests are similar to those in temperate forests (Vitousek 1984, Tanner et al. 1998, Hedin et al. 2009). Montane forests should therefore be excluded to evaluate the hypothesis that N is available in excess of plant demand in lowland tropical forests. In addition, three of the four lowland experiments evaluated by LeBauer and Treseder (2008) were conducted in

TABLE 2. Increases (%) with nutrient addition in concentrations of the added nutrient for soils, fine litter, and sun-exposed canopy leaves.

	Increase with addition of same nutrient (%)		
Element	Soil†	Fine litter‡	Canopy leaves§
K	24	16	18
N	47	7	5
P	34	27	38

† For samples stored at 2–4°C for 24–48 h and extracted in 2 mol/L KCl for ammonium and nitrate, Bray's P1 solution for P, and 1 mol/L NH_4Cl for K. The value for N refers to nitrate; ammonium was unaffected (Koehler et al. 2009, Yavitt et al. 2010).

‡ Kaspari et al. (2008).

§ Mean value for one individual of each of three species for each 40 × 40 m plot. The increase for N is only marginally significant ($P = 0.087$).

young secondary forests, where nutrient limitation is expected as previously discussed (see *Discussion: Responses to phosphorus addition*).

Just two N fertilization experiments have evaluated community-level responses in old-growth, lowland tropical forests (Mirmanto et al. 1999; see *Results*). Fine-litter production increased significantly with N addition just 8–20 months after the first N application in Borneo (Mirmanto et al. 1999). In contrast in our experiment, N alone had no significant effects on fine-root biomass, fine-litter production, and tree growth rates; however, the combined addition of N and K was associated with a significant increase in the growth rates of the three smaller size classes of trees (Fig. 1) and a marginally significant reduction in fine-root biomass (Fig. 3B).

Co-limitation by N and K is indicated, especially for sapling and pole-sized trees. Thus, the two experiments conducted in mature, lowland tropical forests suggest limitation by N (Mirmanto et al. 1999) or co-limitation by N and K (see *Results*).The hypothesis that N is available in excess of plant demand in mature lowland tropical forests is not supported.

Responses to potassium addition

In contrast to N and P, the possibility that K might limit tropical forest plants has been entirely overlooked and there are no prior K addition experiments from lowland tropical forests to compare with our results (Tripler et al. 2006). This is surprising because K, like P, is derived from rock and monovalent K^+ ions are particularly prone to leaching losses in the humid tropics (Veldkamp et al. 1990, Hedin et al. 2003). In our experiment, K addition decreased fine-root biomass (Fig. 3A), increased fine-root turnover (Yavitt et al. 2010), decreased seedling allocation to roots, increased seedling height growth rates (L. Santiago, *unpublished data*), and when combined with N addition increased growth rates of smaller trees (Fig. 1). Limitation by K is clearly indicated. The possibility that K might limit plants in tropical forests deserves greater attention.

The mechanism linking K addition to root dynamics is unclear. In the laboratory, K-deficient plants are unable to increase allocation to root growth because K^+ is required to load sucrose into the phloem, and K deficiency impedes sucrose export from leaves to support increased allocation to roots (Hermans et al. 2006). Nonetheless, the addition of K was associated with strong and consistent changes in root dynamics in our experiment. These included significant decreases in seedling allocation to roots (L. Santiago, *unpublished data*) and in stand-level fine-root biomass detected with both root cores and minirhizotrons (Fig. 3A; Yavitt et al. 2010). Allocation shifted away from roots with K addition. The discrepancy with laboratory experiments (Hermans et al. 2006) suggests unknown links between root allocation and K availability.

PLATE 1. Most mature tropical forests include a small number of very large trees. These largest trees make disproportionate contributions to stand-level wood production, and their rarity introduces large variation in wood production among our experimental plots. Three technicians are required to measure the diameter of the largest trees above buttresses and other deformities of the lower trunk. The photograph shows a canopy emergent *Cavanillesia platanifolia* (Bonpl.) Kunth being measured above the swollen lower trunk characteristic of many species in the family Bombacaceae. Photo credit: Marcos Guerra, STRI.

CONCLUSIONS

After 11 years of chronic nutrient addition, our experiment provides evidence for co-limitation of plants growing on a relatively fertile lowland tropical forest soil by N, P, and K. The addition of K reduced fine-root biomass at the community level, reduced allocation to roots in seedlings, and increased seedling height growth rates. The simultaneous addition of K plus N increased growth rates of small saplings and pole-sized trees. And, the addition of P increased fine-litter production, which is dominated by large trees and lianas. Thus, there is also a suggestion that different nutrients limit different forest strata and/or plants of different sizes.

Clearly many more fertilization experiments must be conducted in mature, lowland tropical forests before the hypothesis that P limits primary production while N is available in excess of plant demand on moderately to highly weathered tropical soils can be fully evaluated (Vitousek 1984, Vitousek and Sanford 1986, Hedin et al. 2009). In the meantime, the three fertilization experiments that evaluated community-level responses in mature, lowland tropical forests (Mirmanto et al. 1999, Newbery et al. 2002; see *Results*) suggest that N ($N = 2$ out of two experiments), P ($N = 2$ out of three experiments), and a second rock-derived nutrient, K ($N = 1$; see *Results*) limit plant growth and/or fine-litter production. These results and long-standing observations that nutrients other than N, P, and K influence plant function and plant distributions in lowland tropical forests (e.g., Baillie et al. 1987, Cuevas and Medina 1988) suggest that the full range of nutrients that might limit plants in lowland tropical forests should now be considered.

Acknowledgments

Rufino Gonzalez and Omar Hernandez have added nutrients since 1998 and collected most of the data presented here. Funding was provided by grants from the Scholarly Studies program of the Smithsonian Institution and the Andrew W. Mellon Foundation to S. J. Wright and from NOAA (proposal number GC07-172) to L. O. Hedin.

Literature Cited

Baillie, I. C., P. S. Ashton, M. N. Court, J. A. R. Anderson, E. A. Fitzpatrick, and J. Tinsley. 1987. Site characteristics and the distribution of tree species in mixed Dipterocarp forest on Tertiary sediments in central Sarawak, Malaysia. Journal of Tropical Ecology 3:201–220.

Barron, A. R., N. Wurzburger, J. P. Bellenger, S. J. Wright, A. M. L. Kraepiel, and L. O. Hedin. 2009. Molybdenum limitation of asymbiotic nitrogen fixation in tropical forest soils. Nature Geoscience 2:42–45.

Barthold, F. K., R. F. Stallard, and H. Elsenbeer. 2008. Soil nutrient–landscape relationships in a lowland tropical rainforest in Panama. Forest Ecology and Management 255:1135–1148.

Campo, J., and C. Vazquez-Yanes. 2004. Effects of nutrient limitation on aboveground carbon dynamics during tropical dry forest regeneration in Yucatan, Mexico. Ecosystems 7:311–319.

Cavelier, J., S. J. Wright, and J. Santamaria. 1999. Effects of irrigation on fine root biomass and production, litterfall and trunk growth in a semideciduous lowland forest in Panama. Plant and Soil 211:207–213.

Chave, J., et al. 2005. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologia 145:87–99.

Clark, D. B., D. A. Clark, and S. F. Oberbauer. 2010. Annual wood production in a tropical rain forest in NE Costa Rica linked to climatic variation but not to increasing CO_2. Global Change Biology 16:747–759.

Corre, M. D., E. Veldkamp, J. Arnold, and S. J. Wright. 2010. Impact of elevated N input on soil N cycling and losses in old-growth lowland and montane forests in Panama. Ecology 91:1715–1729.

Cuevas, E., and E. Medina. 1988. Nutrient dynamics within Amazonian forests. II. Fine root growth, nutrient availability and leaf litter decomposition. Oecologia 76:222–235.

Davidson, E. A., C. J. R. de Carvalho, I. C. G. Vieira, R. D. Figueiredo, P. Moutinho, F. Y. Ishida, M. T. P. dos Santos, J. B. Guerrero, K. Kalif, and R. T. Saba. 2004. Nitrogen and phosphorus limitation of biomass growth in a tropical secondary forest. Ecological Applications 14:S150–S163.

Elser, J. J., M. E. S. Bracken, E. E. Cleland, D. S. Gruner, W. S. Harpole, H. Hillebrand, J. T. Ngai, E. W. Seabloom, J. B. Shurin, and J. E. Smith. 2007. Global analysis of nitrogen and phosphorus limitation of primary producers in freshwater, marine and terrestrial ecosystems. Ecology Letters 10:1135–1142.

Feeley, K. J., S. J. Wright, M. N. N. Supardi, A. R. Kassim, and S. J. Davies. 2007. Decelerating growth in tropical forest trees. Ecology Letters 10:461–469.

Fisher, R. F., and D. Binkley. 2000. Ecology and management of forest soils. Third edition. John Wiley and Sons, New York, New York, USA.

Fyllas, N. M., et al. 2009. Basin-wide variations in foliar properties of Amazonian forest: phylogeny, soils and climate. Biogeosciences 6:2677–2708.

Hedin, L. O., E. N. J. Brookshire, D. N. L. Menge, and A. R. Barron. 2009. The nitrogen paradox in tropical forest ecosystems. Annual Review of Ecology, Evolution and Systematics 40:613–635.

Hedin, L. O., P. M. Vitousek, and P. A. Matson. 2003. Nutrient losses over four million years of tropical forest development. Ecology 84:2231–2255.

Hermans, C., J. P. Hammond, P. J. White, and N. Verbruggen. 2006. How do plants respond to nutrient shortage by biomass allocation? Trends in Plant Science 11:610–617.

IUSS Working Group WRB. 2006. World reference base for soil resources. World Soil Resources Reports, Number 103. Food and Agriculture Organization, Rome, Italy.

Kaspari , M., S. J. Wright, J. B. Yavitt, K. E. Harms, M. Garcia, and M. Santana. 2008. Multiple nutrients limit litterfall and decomposition in a tropical forest. Ecology Letters 11:35–43.

Koehler, B., M. D. Corre, E. Veldkamp, H. Wullaert, and S. J. Wright. 2009. Immediate and long-term nitrogen oxide emissions from tropical forest soils exposed to elevated nitrogen input. Global Change Biology 15:2049–2066.

Lambers, H., J. A. Raven, G. R. Shaver, and S. E. Smith. 2008. Plant nutrient-acquisition strategies change with soil age. Trends in Ecology and Evolution 23:95–103.

LeBauer, D. S., and K. K. Treseder. 2008. Nitrogen limitation of net primary productivity in terrestrial ecosystems is globally distributed. Ecology 89:371–379.

McGroddy, M. E., T. Daufresne, and L. O. Hedin. 2004. Scaling of C:N:P stoichiometry in forests worldwide: implications of terrestrial redfield-type ratios. Ecology 85:2390–2401.

Mirmanto, E., J. Proctor, J. Green, L. Nagy, and Suriantata.1999. Effects of nitrogen and phosphorus fertilization in a lowland evergreen rainforest. Philosophical Transactions of the Royal Society B 354:1825–1829.

Muller-Landau, H. C., et al. 2006. Comparing tropical forest tree size distributions with the predictions of metabolic ecology and equilibrium models. Ecology Letters 9:589–602.

Newbery, D. M., G. B. Chuyong, J. J. Green, N. C. Songwe, F. Tchuenteu, and L. Zimmermann. 2002. Does low phosphorus supply limit seedling establishment and tree growth in groves of ectomycorrhizal trees in a central African rainforest? New Phytologist 156:297–311.

Patiño , S., et al. 2009. Branch xylem density variations across the Amazon Basin. Biogeosciences 6:545–568.

Porder, S., P. M. Vitousek, O. A. Chadwick, C. P. Chamberlain, and G. E. Hilley. 2007. Uplift, erosion, and phosphorus limitation in terrestrial ecosystems. Ecosystems 10:158–170.

Proctor, J. 1983. Tropical forest litterfall. I. Problems of data comparison. Pages 267–273 *in* S. L. Sutton, T. C. Whitmore, and A. C. Chadwick, editors. Tropical rain forest: ecology and management. Blackwell Scientific Publications, Oxford, UK.

Sayer, E. J., and E. V. J. Tanner. 2010. Experimental investigation of the importance of litterfall in lowland semi-

evergreen tropical forest nutrient cycling. Journal of Ecology 98:1052–1062.
Stewart, R. H., J. L. Stewart, and W. P. Woodring. 1980. Geologic map of the Panama Canal and vicinity, Republic of Panama. U.S. Geological Survey Miscellaneous Investigations Series Map I-1232.
Tanner, E. V. J., V. Kapos, and W. Franco. 1992. Nitrogen and phosphorus fertilization effects on Venezuelan montane forest trunk growth and litterfall. Ecology 73:78–86.
Tanner, E. V. J., P. M. Vitousek, and E. Cuevas. 1998. Experimental investigation of nutrient limitation of forest growth on wet tropical mountains. Ecology 79:10–22.
Tripler, C. E., S. S. Kaushal, G. E. Likens, and M. T. Walter. 2006. Patterns in potassium dynamics in forest ecosystems. Ecology Letters 9:451–466.
Veldkamp, E., A. G. Jongmans, T. C. Feijtel, A. Veldkamp, and N. van Breeman. 1990. Alkali basalt gravel weathering in Quaternary Allier River terraces, Limagne, France. Soil Science Society of America Journal 54:1043–1048.
Vitousek, P. M. 1984. Litterfall, nutrient cycling and nutrient limitation in tropical forests. Ecology 65:285–298.
Vitousek, P. M. 2004. Nutrient cycling and limitation: Hawai'i as a model system. Princeton University Press, Princeton, New Jersey, USA.
Vitousek, P. M., S. Porder, B. Z. Houlton, and O. A. Chadwick. 2010. Terrestrial phosphorus limitation: mechanisms, implications, and nitrogen–phosphorus interactions. Ecological Applications 20:5–15.
Vitousek, P. M., and R. L. Sanford, Jr. 1986. Nutrient cycling in moist tropical forest. Annual Review of Ecology and Systematics 17:137–167.
Walker, T. W., and J. K. Syers. 1976. The fate of phosphorus during pedogenesis. Geoderma 15:1–19.
Winer, B. J. 1971. Statistical principles in experimental design. McGraw-Hill, New York, New York, USA.
Wright, S. J. 2010. The future of tropical forests. Annals of the New York Academy of Sciences 1195:1–27.
Wright, S. J., et al. 2010. Functional traits and the growth–mortality trade-off in tropical trees. Ecology 91:3664–3674.
Wright, S. J., H. C. Muller-Landau, O. Calderon, and A. Hernandez. 2005. Annual and spatial variation in seedfall and seedling recruitment in a neotropical forest. Ecology 86:848–860.
Yavitt, J. B., K. E. Harms, M. N. Garcia, M. J. Mirabello, and S. J. Wright. 2010. Soil fertility and fine root dynamics in response to four years of nutrient (N, P, K) fertilization in a lowland tropical moist forest, Panama. Austral Ecology. [doi: 10.1111/j.1442-9993.2010.02157.x]
Yavitt, J. B., K. E. Harms, M. N. Garcia, S. J. Wright, F. He, and M. J. Mirabelo. 2009. Spatial heterogeneity of soil chemical properties in a lowland tropical moist forest, Panama. Australian Journal of Soil Research 47:674–687.
Yavitt, J. B., S. J. Wright, and R. K. Wieder. 2004. Seasonal drought and dry-season irrigation influence leaf-litter nutrients and soil enzymes in a moist, lowland forest in Panama. Austral Ecology 29:177–188.

APPENDIX A

Maps showing the location of the study site, its topography, and locations of each experimental plot (*Ecological Archives* E092-136-A1).

APPENDIX B

ANOVA tables for the factorial, incomplete block design for the eight response variables analyzed in this article (*Ecological Archives* E092-136-A2).

SUPPLEMENT

All data sets analyzed in this article (*Ecological Archives* E092-136-S1).

Ecological Archives E092-136-A1

S. Joseph Wright, Joseph B. Yavitt, Nina Wurzburger, Benjamin L. Turner, Edmund V. J. Tanner, Emma J. Sayer, Louis S. Santiago, Michael Kaspari, Lars O. Hedin, Kyle E. Harms, Milton N. Garcia, and Marife D. Corre. **2011. Potassium, phosphorus, or nitrogen limit root allocation, tree growth, and litter production in a lowland tropical forest. *Ecology* 92:1616–1625.**

Appendix A. Maps showing the location of the study site, its topography and locations of each experimental plot.

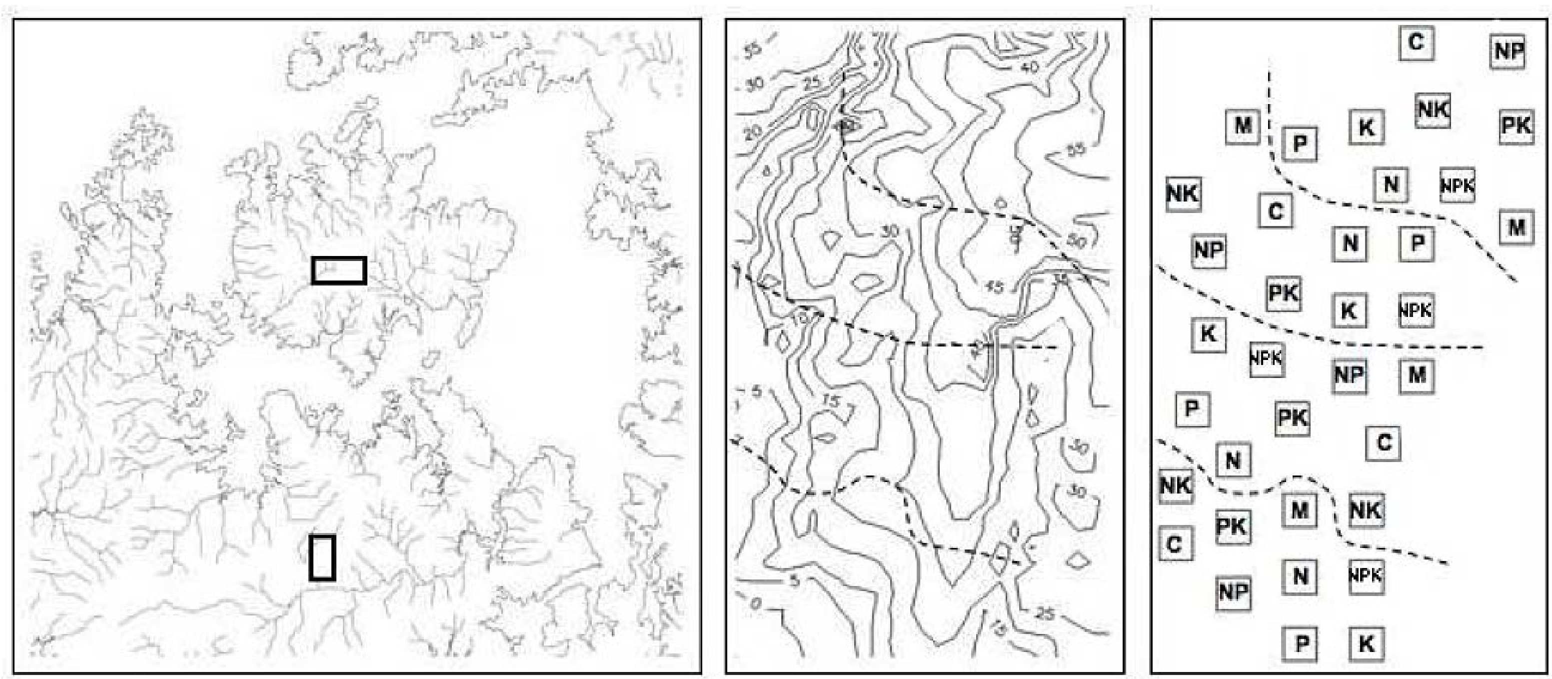

FIG. A1. Maps of the study area. The left panel shows the region. White represents Gatun Lake. The large island is Barro Colorado Island (BCI). The northern rectangle is the Forest Dynamics Plot (1000 m by 500 m) on BCI. The southern rectangle is the fertilization site (480 m by 800 m) on the Gigante Peninsula in the Barro Colorado Nature Monument. The central panel shows the topography of the fertilization site. The right panel shows the placement of treatments. The dashed lines separate four replicates of the full factorial N-P-K experiment. Treatments are represented by the combination of nutrients added (N, P, and/or K), by C for controls and by M for micronutrients. The micronutrient treatment is not addressed here.

[Back to E092-136]

Ecological Archives E092-136-A2

S. Joseph Wright, Joseph B. Yavitt, Nina Wurzburger, Benjamin L. Turner, Edmund V. J. Tanner, Emma J. Sayer, Louis S. Santiago, Michael Kaspari, Lars O. Hedin, Kyle E. Harms, Milton N. Garcia, and Marife D. Corre. 2011. Potassium, phosphorus, or nitrogen limit root allocation, tree growth, and litter production in a lowland tropical forest. *Ecology* 92:1616–1625.

Appendix B. ANOVA tables for the factorial, incomplete block design for the eight response variables analyzed in this article.

TABLE B1. ANOVA for relative growth rates (RGR × 100) of trees with initial DBH ≥ 10 cm.

Between Plots					
Source	SS	df	MS	F	P
Between blocks					
Rep	0.341	3	0.114	0.295	0.828
Block(Rep)	0.639	4	0.160	0.415	0.795
Within blocks					
N	0.036	1	0.036	0.093	0.764
P	0.306	1	0.306	0.796	0.384
K	0.346	1	0.346	0.899	0.356
N*P	0.087	1	0.087	0.227	0.640
N*K	1.698	1	1.698	4.411	0.050
P*K	0.014	1	0.014	0.037	0.849
Error	6.929	18	0.385		
Within Plots					
Source	SS	df	MS	F	P
Between blocks					
Year*Rep	0.555	3	0.185	3.059	0.055
Yr*Block(Rep)	0.556	4	0.139	2.300	0.098
Within blocks					
Year	0.908	1	0.908	15.030	0.001
Year*N	0.012	1	0.012	0.200	0.660
Year*P	0.480	1	0.480	7.945	0.011
Year*K	0.003	1	0.003	0.055	0.817
Year*N*P	0.000	1	0.000	0.002	0.967
Year*N*K	0.088	1	0.088	1.461	0.242
Year*P*K	0.116	1	0.116	1.925	0.182
Error	1.088	18	0.060		

TABLE B2. ANOVA for relative growth rates (RGR × 100) of trees with initial DBH between 5.0 and 9.9 cm.

Between Plots					
Source	SS	df	MS	F	P
Between blocks					
Rep	0.901	3	0.300	0.695	0.567
Block(Rep)	1.384	4	0.346	0.801	0.540
Within blocks					
N	0.017	1	0.017	0.040	0.844
P	0.000	1	0.000	0.000	0.996
K	0.060	1	0.060	0.139	0.714
N*P	0.342	1	0.342	0.793	0.385
N*K	0.090	1	0.090	0.209	0.653
P*K	0.945	1	0.945	2.190	0.156
Error	7.773	18	0.432		
Within Plots					
Source	SS	df	MS	F	P
Between blocks					
Year*Rep	1.088	3	0.363	1.523	0.243
Yr*Block(Rep)	3.997	4	0.999	4.195	0.014
Within blocks					
Year	7.960	1	7.960	33.416	0.000
Year*N	0.321	1	0.321	1.348	0.261
Year*P	0.103	1	0.103	0.431	0.520
Year*K	0.108	1	0.108	0.455	0.509
Year*N*P	0.001	1	0.001	0.006	0.940
Year*N*K	1.624	1	1.624	6.819	0.018
Year*P*K	0.974	1	0.974	4.091	0.058
Error	4.288	18	0.238		

TABLE B3. ANOVA for relative growth rates (RGR × 100) of trees with initial DBH between 2.5 and 4.9 cm.

Between Plots					
Source	SS	df	MS	F	P
Among blocks					
Rep	1.284	3	0.428	0.775	0.523
Block(Rep)	3.826	4	0.956	1.733	0.187
Within blocks					
N	0.000	1	0.000	0.000	0.995
P	0.025	1	0.025	0.045	0.835
K	0.140	1	0.140	0.254	0.620
N*P	0.102	1	0.102	0.185	0.673
N*K	0.111	1	0.111	0.201	0.660
P*K	0.342	1	0.342	0.620	0.441
Error	9.936	18	0.552		
Within Plots					
Source	SS	df	MS	F	P
Among blocks					
Year*Rep	0.444	3	0.148	0.649	0.594
Yr*Block(Rep)	2.387	4	0.597	2.614	0.070
Within blocks					
Year	23.746	1	23.746	104.01	0.000
Year*N	0.139	1	0.139	0.608	0.446
Year*P	0.053	1	0.053	0.234	0.635
Year*K	1.210	1	1.210	5.301	0.033
Year*N*P	0.727	1	0.727	3.186	0.091
Year*N*K	1.903	1	1.903	8.335	0.010
Year*P*K	0.024	1	0.024	0.106	0.749
Error	4.110	18	0.228		

TABLE B4. ANOVA for relative growth rates (RGR × 100) of trees with initial DBH between 1.0 and 2.4 cm.

Among Plots					
Source	SS	df	MS	F	P
Among blocks					
Rep	10.572	3	3.524	1.718	0.199
Block(Rep)	13.454	4	3.364	1.640	0.208
Within blocks					
N	2.996	1	2.996	1.460	0.242
P	0.189	1	0.189	0.092	0.765
K	0.283	1	0.283	0.138	0.714
N*P	3.428	1	3.428	1.671	0.212
N*K	0.001	1	0.001	0.000	0.984
P*K	1.354	1	1.354	0.660	0.427
Error	36.924	18	2.051		
Within Plots					
Source	SS	df	MS	F	P
Among blocks					
Year*Rep	1.906	3	0.635	1.326	0.297
Yr*Block(Rep)	7.323	4	1.831	3.823	0.020
Within blocks					
Year	44.677	1	44.677	93.294	0.000
Year*N	0.267	1	0.267	0.559	0.465
Year*P	0.527	1	0.527	1.101	0.308
Year*K	1.568	1	1.568	3.275	0.087
Year*N*P	0.802	1	0.802	1.675	0.212
Year*N*K	2.607	1	2.607	5.445	0.031
Year*P*K	0.129	1	0.129	0.270	0.610
Error	8.620	18	0.479		

TABLE B5. ANOVA for fine root biomass density in surface soils (0 to 5 cm depth). G-G represents within subjects *P* values after implementing the Greenhouse-Geisser correction for violations of the compound symmetry assumption of repeated measures ANOVA.

Among Plots

Source	SS	df	MS	F	P
Among blocks					
Rep	0.904	3	0.301	0.549	0.655
Block(rep)	1.027	4	0.257	0.468	0.759
Within blocks					
N	0.263	1	0.263	0.479	0.498
P	0.767	1	0.767	1.396	0.253
K	5.319	1	5.319	9.687	0.006
N*P	0.343	1	0.343	0.625	0.440
N*K	0.022	1	0.022	0.040	0.843
P*K	1.351	1	1.351	2.460	0.134
Error	9.884	18	0.549		

Within Plots

Source	SS	df	MS	F	P	G-G
Between blocks						
Year*Rep	5.157	6	0.859	3.545	0.007	0.013
Year*Block(rep)	1.875	8	0.234	0.967	0.477	0.469
Within blocks						
Year	31.142	2	15.571	64.222	0.000	0.000
Year*N	0.014	2	0.007	0.029	0.972	0.949
Year*P	0.212	2	0.106	0.437	0.650	0.608
Year*K	0.876	2	0.438	1.806	0.179	0.187
Year*N*P	0.122	2	0.061	0.251	0.780	0.732
Year*N*K	1.559	2	0.780	3.215	0.052	0.064
Year*P*K	0.816	2	0.408	1.683	0.200	0.206
Error	8.728	36	0.242			

TABLE B6. ANOVA for fine root biomass density in subsurface soils (5 to 10 cm depth). G-G represents within subjects *P* values after implementing the Greenhouse-Geisser correction for violations of the compound symmetry assumption of repeated measures ANOVA.

Among Plots					
Source	SS	df	MS	F	P
Among blocks					
Rep	0.763	3	0.254	1.464	0.258
Block(rep)	0.480	4	0.120	0.691	0.608
Within blocks					
N	0.094	1	0.094	0.541	0.471
P	0.049	1	0.049	0.281	0.603
K	0.206	1	0.206	1.184	0.291
N*P	0.574	1	0.574	3.305	0.086
N*K	0.192	1	0.192	1.106	0.307
P*K	0.294	1	0.294	1.693	0.210
Error	3.127	18	0.174		

Within Plots						
Source	SS	df	MS	F	P	G-G
Among blocks						
Year*Rep	1.362	6	0.227	2.188	0.067	0.085
Year*Block(rep)	0.536	8	0.067	0.646	0.734	0.702
Within blocks						
Year	13.134	2	6.567	63.301	0.000	0.000
Year*N	0.226	2	0.113	1.089	0.347	0.337
Year*P	0.013	2	0.006	0.061	0.941	0.907
Year*K	0.167	2	0.084	0.805	0.455	0.432
Year*N*P	0.254	2	0.127	1.225	0.306	0.301
Year*N*K	0.141	2	0.070	0.679	0.513	0.483
Year*P*K	0.129	2	0.065	0.622	0.542	0.510
Error	3.735	36	0.104			

TABLE B7. ANOVA for fine litter production. G-G represents within subjects *P* values after implementing the Greenhouse-Geisser correction for violations of the compound symmetry assumption of repeated measures ANOVA.

Among Plots					
Source	SS	df	MS	F	P
Among blocks					
Rep	1127.29	3	375.763	4.663	0.014
Block (rep)	211.54	4	52.885	0.656	0.630
Within blocks					
N	141.71	1	141.708	1.758	0.201
P	330.44	1	330.436	4.100	0.058
K	50.336	1	50.336	0.625	0.440
N*P	101.22	1	101.216	1.256	0.277
N*K	0.934	1	0.934	0.012	0.915
P*K	10.92	1	10.922	0.136	0.717
Error	1450.60	18	80.589		

Within Plots						
Source	SS	df	MS	F	P	G-G
Among blocks						
Year*Rep	105.32	30	3.511	1.009	0.461	0.446
Yr*Block(rep)	84.672	40	2.117	0.608	0.968	0.837
Within blocks						
Year	60.979	10	6.098	1.753	0.072	0.163
Year*N	66.715	10	6.672	1.918	0.045	0.133
Year*P	49.261	10	4.926	1.416	0.176	0.246
Year*K	44.964	10	4.496	1.292	0.238	0.285
Year*N*P	20.026	10	2.003	0.576	0.833	0.646
Year*N*K	15.867	10	1.587	0.456	0.916	0.728
Year*P*K	14.219	10	1.422	0.409	0.941	0.762
Error	626.241	180	3.479			

TABLE B8. ANOVA for above-ground net primary production.

Among Plots					
Source	SS	df	MS	F	P
Among blocks					
REP	271.210	3	90.403	3.459	0.038
BLOCK(REP)	63.379	4	15.845	0.606	0.663
Within blocks					
N	3.992	1	3.992	0.153	0.701
P	14.234	1	14.234	0.545	0.470
K	16.256	1	16.256	0.622	0.441
N*P	83.396	1	83.396	3.191	0.091
N*K	41.033	1	41.033	1.570	0.226
P*K	8.443	1	8.443	0.323	0.577
Error	470.379	18	26.132		
Within Plots					
Source	SS	df	MS	F	P
Among blocks					
Year*Rep	10.792	3	3.597	0.655	0.590
Yr*Block(rep)	8.864	4	2.216	0.404	0.803
Within blocks					
Year	8.204	1	8.204	1.495	0.237
Year*N	10.671	1	10.671	1.944	0.180
Year*P	9.049	1	9.049	1.649	0.215
Year*K	10.880	1	10.880	1.982	0.176
Year*N*P	2.726	1	2.726	0.497	0.490
Year*N*K	0.432	1	0.432	0.079	0.782
Year*P*K	0.623	1	0.623	0.114	0.740
Error	98.805	18	5.489		

[Back to E092-136]

S. Joseph Wright, Joseph B. Yavitt, Nina Wurzburger, Benjamin L. Turner, Edmund V. J. Tanner, Emma J. Sayer, Louis S. Santiago, Michael Kaspari, Lars O. Hedin, Kyle E. Harms, Milton N. Garcia, and Marife D. Corre. 2011. Potassium, phosphorus, or nitrogen limit root allocation, tree growth, and litter production in a lowland tropical forest. *Ecology* 92:1616–1625.

Supplement

All data sets analyzed in this article.
***Ecological Archives* E092-136-S1.**

Author(s)

S. Joseph Wright
Smithsonian Tropical Research Instittue
Apartado 0843-03092
Balboa
Republic of Panama
E-mail: wrightj@si.edu

Joseph B. Yavitt
Dept. of Natural Resources
Cornell University
Ithaca, NY, 14853 USA

Nina Wurzburger
Dept. of Ecology and Evolutionary Biology
Princeton University
Princeton, NJ 08540 USA

Benjamin L. Turner
Smithsonian Tropical Research Instittue
Apartado 0843-03092
Balboa
Republic of Panama

Edmund V. J. Tanner
Dept. of Plant Sciences
Univ. of Cambridge
Cambridge CB2 3EA UK

Emma J. Sayer
Centre for Ecology and Hydrology
Benson Lane
Crowmarsh Gifford, Wallingford OX10 8BB UK

Louis S. Santiago
Dept. of Botany and Plant Sciences
Univ. of California
Riverside, CA 92521 USA

Michael Kaspari
Dept. of Zoology
Univ. of Oklahoma
Norman, OK 73019-0235 USA

Lars O. Hedin
Dept. of Ecology and Evolutionary Biology
Princeton Univ.
Princeton, NJ 08540 USA

Kyle E. Harms
Dept. of Biological Sciences
Louisiana State Univ.
Baton Rouge, LA 70803 USA

Milton N. Garcia
Smithsonian Tropical Research Instittue
Apartado 0843-03092
Balboa
Republic of Panama

Marife D. Corre
Soil Science, Büsgen Inst.
Georg-August-Univ.
Göttingen, Büsgenweg 2
37077 Göttingen, Germany

File list

Data.txt

Description

The data.txt file is a tab-delimited ascii file. It contains all response variables presented in this article. The first row contains the capitalized variable names used in column definitions below.

Column definitions:

1. PLOT – An integer to identify the 32 experimental plots

2. N – A value of 1 (one) identifies an N addition plot. A value of 0 (zero) identifies a plot that did not receive added N.

3. P – A value of 1 (one) identifies a P addition plot. A value of 0 (zero) identifies a plot that did not receive added P.

4. K – A value of 1 (one) identifies a K addition plot. A value of 0 (zero) identifies a plot that did not receive added K.

5. BLOCK – An integer to identify the two blocks within each replicate. In the balanced, incomplete blocks design, one block in each replicate includes the treatments +N, +P, +K and +NPK and the second block in each replicate includes the treatments CONTROL, +NP, +NK and +PK. Values are 0 (zero) or 1 (one).

6. REP - An integer to identify the four replicates of the factorial NPK experiment.

7. RGR14_25 – The relative growth rate between 1997 and 2000 for saplings with DBH between 10 and 24 mm DBH in 1997.

8. RGR46_25 – The relative growth rate between 2000 and 2008 for saplings with DBH between 10 and 24 mm DBH in 2000.

9. RGR14_50 – The relative growth rate between 1997 and 2000 for saplings with DBH between 25 and 49 mm DBH in 1997.

10. RGR46_50 – The relative growth rate between 2000 and 2008 for saplings with DBH between 25 and 49 mm DBH in 2000.

11. RGR14_100 – The relative growth rate between 1997 and 2000 for saplings with DBH between 50 and 99 mm DBH in 1997.

12. RGR46_100 – The relative growth rate between 2000 and 2008 for saplings with DBH between 50 and 99 mm DBH in 2000.

13. RGR14_CAN – The relative growth rate between 1997 and 2000 for saplings with DBH greater than 99 mm DBH in 1997.

14. RGR46_CAN – The relative growth rate between 2000 and 2008 for saplings with DBH greater than 99 mm DBH in 2000.

15. ANPP9800 – Above-ground net primary production between 1998 and 2000. ANPP is the sum of wood and fine litter production. Units are Mg ha^{-1} yr^{-1}.

16. ANPP0008 – Above-ground net primary production between 2000 and 2008. ANPP is the sum of wood and fine litter production. Units are Mg ha^{-1} yr^{-1}.

17. F2000_5CM – Fine root biomass between 0 and 5 cm depth in April 2000. Fine roots are < 2 mm in diameter. Units are kg m^{-3}.

18. C2000_5CM – Coarse root biomass between 0 and 5 cm depth in April 2000. Coarse root diameters are between 2 and 5 mm. Units are kg m^{-3}. These data were not analyzed due to the large numbers of zeros, but are included here to facilitate comparison with other studies.

19. F2008_5CM – Fine root biomass between 0 and 5 cm depth in November 2008. Fine roots are < 2 mm in diameter. Units are kg m^{-3}.

20. C2008_5CM – Coarse root biomass between 0 and 5 cm depth in November 2008. Coarse root diameters are between 2 and 5 mm. Units are kg m^{-3}. These data were not analyzed due to the large numbers of zeros, but are included here to facilitate comparison with other studies.

21. F2009_5CM – Fine root biomass between 0 and 5 cm depth in April 2009. Fine roots are < 2 mm in diameter. Units are kg m^{-3}.

22. C2009_5CM – Coarse root biomass between 0 and 5 cm depth in April 2009. Coarse root diameters are between 2 and 5 mm. Units are kg m^{-3}. These data were not analyzed due to the large numbers of zeros, but are included here to facilitate comparison with other studies.

23. F2000_10CM – Fine root biomass between 5 and 10 cm depth in April 2000. Fine roots are < 2 mm in diameter. Units are kg m^{-3}.

24. C2000_10CM – Coarse root biomass between 5 and 10 cm depth in April 2000. Coarse root diameters are between 2 and 5 mm. Units are kg m^{-3}. These data were not analyzed due to the large numbers of zeros, but are included here to facilitate comparison with other studies.

25. F2008_10CM – Fine root biomass between 5 and 10 cm depth in November 2008. Fine roots are < 2 mm in diameter. Units are kg m^{-3}.

26. C2008_10CM – Coarse root biomass between 5 and 10 cm depth in November 2008. Coarse root diameters are between 2 and 5 mm. Units are kg m^{-3}. These data were not analyzed due to the large numbers of zeros, but are included here to facilitate comparison with other studies.

27. F2009_10CM – Fine root biomass between 5 and 10 cm depth in April 2009. Fine roots are < 2 mm in diameter. Units are kg m^{-3}.

28. C2009_10CM – Coarse root biomass between 5 and 10 cm depth in April 2000. Coarse root diameters are between 2 and 5 mm. Units are kg m^{-3}. These data were not analyzed due to the large numbers of zeros, but are included here to facilitate comparison with other studies.

29. L_1998 – Leaf litter production in 1998. Units are Mg ha^{-1} yr^{-1}.

30. F_1998 – Production of reproductive structures in 1998. Units are Mg ha^{-1} yr^{-1}.

31. B_1998 – Small branch (< 2 cm in diameter) production in 1998. Units are Mg ha^{-1} yr^{-1}.

32. D_1998 – Production of frass, dust and other small particles in 1998. Units are Mg ha^{-1} yr^{-1}.

33. T_1998 – Total fine litter production in 1998. Units are Mg ha^{-1} yr^{-1}.

34. L_1999 – Leaf litter production in 1999. Units are Mg ha^{-1} yr^{-1}.

35. F_1999 – Production of reproductive structures in 1999. Units are Mg ha^{-1} yr^{-1}.

36. B_1999 – Small branch (< 2 cm in diameter) production in 1999. Units are Mg ha^{-1} yr^{-1}.

37. D_1999 – Production of frass, dust and other small particles in 1999. Units are Mg ha^{-1} yr^{-1}.

38. T_1999 – Total fine litter production in 1999. Units are Mg ha^{-1} yr^{-1}.

39. L_2000 – Leaf litter production in 2000. Units are Mg ha^{-1} yr^{-1}.

40. F_2000 – Production of reproductive structures in 2000. Units are Mg ha^{-1} yr^{-1}.

41. B_2000 – Small branch (< 2 cm in diameter) production in 2000. Units are Mg ha^{-1} yr^{-1}.

42. D_2000 – Production of frass, dust and other small particles in 2000. Units are Mg ha^{-1} yr^{-1}.

43. T_2000 – Total fine litter production in 2000. Units are Mg ha^{-1} yr^{-1}.

44. L_2001 – Leaf litter production in 2001. Units are Mg ha^{-1} yr^{-1}.

45. F_2001 – Production of reproductive structures in 2001. Units are Mg ha^{-1} yr^{-1}.

46. B_2001 – Small branch (< 2 cm in diameter) production in 2001. Units are Mg ha^{-1} yr^{-1}.

47. D_2001 – Production of frass, dust and other small particles in 2001. Units are Mg ha^{-1} yr^{-1}.

48. T_2001 – Total fine litter production in 2001. Units are Mg ha^{-1} yr^{-1}.

49. L_2002 – Leaf litter production in 2002. Units are Mg ha^{-1} yr^{-1}.

50. F_2002 – Production of reproductive structures in 2002. Units are Mg ha^{-1} yr^{-1}.

51. B_2002 – Small branch (< 2 cm in diameter) production in 2002. Units are Mg ha^{-1} yr^{-1}.

52. D_2002 – Production of frass, dust and other small particles in 2002. Units are Mg ha^{-1} yr^{-1}.

53. T_2002 – Total fine litter production in 2002. Units are Mg ha^{-1} yr^{-1}.

54. L_2003 – Leaf litter production in 2003. Units are Mg ha^{-1} yr^{-1}.

55. F_2003 – Production of reproductive structures in 2003. Units are Mg ha^{-1} yr^{-1}.

56. B_2003 – Small branch (< 2 cm in diameter) production in 2003. Units are Mg ha^{-1} yr^{-1}.

57. D_2003 – Production of frass, dust and other small particles in 2003. Units are Mg ha^{-1} yr^{-1}.

58. T_2003 – Total fine litter production in 2003. Units are Mg ha^{-1} yr^{-1}.

59. L_2004 – Leaf litter production in 2004. Units are Mg ha^{-1} yr^{-1}.

60. F_2004 – Production of reproductive structures in 2004. Units are Mg ha^{-1} yr^{-1}.

61. B_2004 – Small branch (< 2 cm in diameter) production in 2004. Units are Mg ha^{-1} yr^{-1}.

62. D_2004 – Production of frass, dust and other small particles in 2004. Units are Mg ha^{-1} yr^{-1}.

63. T_2004 – Total fine litter production in 2004. Units are Mg ha^{-1} yr^{-1}.

64. L_2005 – Leaf litter production in 2005. Units are Mg ha^{-1} yr^{-1}.

65. F_2005 – Production of reproductive structures in 2005. Units are Mg ha^{-1} yr^{-1}.

-1 -1

66. B_2005 – Small branch (< 2 cm in diameter) production in 2005. Units are Mg ha yr .

67. D_2005 – Production of frass, dust and other small particles in 2005. Units are Mg ha^{-1} yr^{-1}.

68. T_2005 – Total fine litter production in 2005. Units are Mg ha^{-1} yr^{-1}.

69. L_2006 – Leaf litter production in 2006. Units are Mg ha^{-1} yr^{-1}.

70. F_2006 – Production of reproductive structures in 2006. Units are Mg ha^{-1} yr^{-1}.

71. B_2006 – Small branch (< 2 cm in diameter) production in 2006. Units are Mg ha^{-1} yr^{-1}.

72. D_2006 – Production of frass, dust and other small particles in 2006. Units are Mg ha^{-1} yr^{-1}.

73. T_2006 – Total fine litter production in 2006. Units are Mg ha^{-1} yr^{-1}.

74. L_2007 – Leaf litter production in 2007. Units are Mg ha^{-1} yr^{-1}.

75. F_2007 – Production of reproductive structures in 2007. Units are Mg ha^{-1} yr^{-1}.

76. B_2007 – Small branch (< 2 cm in diameter) production in 2007. Units are Mg ha^{-1} yr^{-1}.

77. D_2007 – Production of frass, dust and other small particles in 2007. Units are Mg ha^{-1} yr^{-1}.

78. T_2007 – Total fine litter production in 2007. Units are Mg ha^{-1} yr^{-1}.

79. L_2008 – Leaf litter production in 2008. Units are Mg ha^{-1} yr^{-1}.

80. F_2008 – Production of reproductive structures in 2008. Units are Mg ha^{-1} yr^{-1}.

81. B_2008 – Small branch (< 2 cm in diameter) production in 2008. Units are Mg ha^{-1} yr^{-1}.

82. D_2008 – Production of frass, dust and other small particles in 2008. Units are Mg ha^{-1} yr^{-1}.

83. T_2008 – Total fine litter production in 2008. Units are Mg ha^{-1} yr^{-1}.

There are no missing values.

Check sum values are:

Column 1 (PLOT): Sum equals 586.

Column 5 (BLOCK): Sum equals 48.

Column 7 (RGR14_25): Sum equals 1.168.

Column 83 (T_2008): Sum equals 350.839.

PLOT N P K BLOCK REP RGR14_25 RGR46_25 RGR14_50 RGR46_50
RGR14_100 RGR46_100 RGR14_CAN RGR46_CAN ANPP9800 ANPP0008 F2000_5CM
C2000_5CM F2008_5CM C2008_5CM F2009_5CM C2009_5CM F2000_10CM C2000_10CM
F2008_10CM C2008_10CM F2009_10CM C2009_10CM L_1998 F_1998 B_1998 D_1998 T_1998
L_1999 F_1999 B_1999 D_1999 T_1999 L_2000 F_2000 B_2000 D_2000 T_2000 L_2001 F_2001 B_2001
D_2001 T_2001 L_2002 F_2002 B_2002 D_2002 T_2002 L_2003 F_2003 B_2003 D_2003 T_2003 L_2004
F_2004 B_2004 D_2004 T_2004 L_2005 F_2005 B_2005 D_2005 T_2005 L_2006 F_2006 B_2006 D_2006
T_2006 L_2007 F_2007 B_2007 D_2007 T_2007 L_2008 F_2008 B_2008 D_2008 T_2008
1 0 1 0 1 1 0.035164324 0.013183721 0.026243962 0.011219047 0.027392462
0.015613347 0.009461194 0.011089997 9.067166738 9.678984704 2.670486376 2.290807232
2.215261862 0.391647568 2.298276887 1.130464307 1.269773364 1.397911892 0.835752483
0.405398523 0.572447161 0.958152958 5.135524798 0.265859285 1.243944637 0.734140715
7.379469435 5.739907728 0.505190311 1.5455594 0.557093426 8.347750865 4.674740484
0.403690888 1.106689735 0.446943483 6.632064591 5.355824683 0.548442907 2.240484429
0.448096886 8.592848904 5.380622837 0.621683968 2.612456747 0.637254902 9.252018454
5.028835063 0.561130334 0.950980392 0.465397924 7.006343714 4.698961938 0.511534025
1.134371396 0.452710496 6.797577855 5.113033449 0.230680507 0.933679354 0.476355248
6.747981546 5.893886967 0.334486736 0.914071511 0.633794694 7.776239908 5.175893887
0.316608997 0.982122261 0.652249135 7.126874279 4.807093426 0.411188005 1.144175317
0.485294118 6.847750865
2 0 0 1 1 1 0.010878705 0.011971766 0.014337666 0.006225537 0.010756519
0.004821832 0.021435118 0.015147941 12.19280716 13.93292955 2.270690094 0.485612427
1.227807487 0.230201171 2.208131738 1.294457177 2.213394449 0 0.971224854 0.152958153
0.319667261 0.164841694 6.903114187 0.523356401 1.432525952 0.683391003 9.542387543
8.095155709 0.660034602 1.113321799 0.595155709 10.46366782 7.459342561 1.326989619
1.215397924 0.443771626 10.44550173 7.404844291 0.876297578 1.576989619 0.448961938
10.30709343 6.24567474 1.057958478 1.636678201 0.525086505 9.465397924 6.544982699
0.910034602 1.848615917 0.5 9.803633218 6.80017301 3.170415225 1.187716263 0.398788927
11.53979239 6.501730104 0.886678201 1.442041522 0.805363322 9.635813149 7.078719723
2.015570934 1.312283737 0.726643599 11.13321799 5.937716263 0.561418685 0.48183391
0.603806228 7.584775087 5.306228374 2.678200692 1.602076125 0.471453287 10.05795848
3 1 1 0 2 1 0.03988521 0.01025097 0.023637633 0.009848843 0.023966362
0.007217186 0.01149687 0.012686202 15.08136518 19.41125582 3.337662338 2.973771327
2.947797301 0.440539852 2.360071301 0.906035141 1.944232238 1.280621339 0.549868432
0.134453782 0.21101774 0.750021221 8.355536332 0.955882353 2.551038062 1.252595156
13.1150519 10.56401384 0.137543253 3.826989619 0.882352941 15.41089965 9.147058824
0.367647059 4.771626298 1.243944637 15.53027682 9.368512111 0.960207612 3.64100346
1.154844291 15.12456747 10.50432526 1.331314879 6.251730104 1.866782007 19.95415225
10.02941176 0.94550173 5.616782007 1.704152249 18.29584775 10.95069204 0.823529412
4.701557093 1.435986159 17.91176471 10.64100346 0.98615917 4.027681661 1.577854671
17.0683391 11.66349481 0.612456747 3.765570934 2.198961938 18.24048443 9.882352941
1.356401384 5.458477509 3.225778547 19.92301038 10.07352941 3.793252595 5.737024221
2.592560554 22.19636678
4 1 0 0 1 1 0.030127966 0.006776646 0.021320476 0.006992031 0.015517366
0.008667509 0.010680565 0.00739397 12.34021252 16.02361213 2.94881589 0.443340973
1.672184025 0.38927086 2.629827689 1.279687633 1.335115865 0.29284441 1.021305492
0.266530855 0.204566675 0.622697564 4.987024221 0.098615917 1.594290657 0.75432526
7.434256055 7.448961938 0.269896194 2.637543253 0.651384083 11.00778547 7.003460208
0.284602076 1.856401384 0.477508651 9.621972318 7.10467128 0.475778547 1.939446367
0.466262976 9.98615917 7.276816609 0.758650519 2.09083045 0.603806228 10.73010381
7.126297578 1.098615917 2.767301038 0.810553633 11.80276817 7.630622837 0.299307958
2.465397924 0.678200692 11.07352941 7.470588235 0.39532872 2.74567474 0.647923875
11.25951557 7.770761246 0.646193772 2.292387543 0.76384083 11.47318339 6.571799308

0.499134948 1.930795848 1.161764706 10.16349481 7.271626298 0.521626298 2.839100346
0.834775087 11.46193772
5 1 1 1 1 1 0.024748875 0.03070801 0.012436422 0.024621099 0.015233332
0.014941278 0.014360356 0.01095048 13.40999877 11.29758844 2.346829641 0 1.361684068
0.05432476 1.823444529 0.985485103 1.606060606 2.823784059 1.18037518 0.489262372 0
0.119174943 6.642445213 0.692618224 2.577854671 0.647058824 10.55997693 7.235294118
0.51384083 1.884083045 0.634948097 10.26816609 6.824682814 1.916955017 1.310841984
0.477508651 10.52998847 6.678200692 0.904267589 2.102652826 0.512687428 10.19780854
3.508650519 0.367358708 0.298731257 0.300461361 4.475201845 3.928489043 2.133217993
0.686851211 0.310265283 7.058823529 4.965974625 0.565167243 0.821799308 0.400230681
6.753171857 4.735870819 0.411764706 0.969434833 0.4088812 6.491349481 4.600922722
0.282583622 0.595732411 0.528835063 6.008073818 4.701268743 1.15916955 0.806228374
0.511534025 7.178200692 5.61822376 0.405420992 0.505767013 0.364475202 6.893886967
6 0 0 0 2 1 0.039640018 0.023759381 0.034864676 0.015434838 0.018591942
0.008304398 0.006769896 0.004563185 9.002030485 9.812050666 3.387827858 0.392666157
1.690348867 0.276716747 2.302521008 0.574314574 1.384517443 1.460147695 0.353959766
0.281639929 0.577200577 0.212206095 5.209919262 1.519031142 1.855247982 0.768742791
9.352941176 5.527681661 0.269319493 1.429642445 0.525951557 7.752595156 4.775663206
0.478662053 0.780853518 0.398500577 6.433679354 6.540369089 0.764129181 1.103806228
0.493079585 8.901384083 6.272202999 0.946943483 1.602652826 0.60899654 9.430795848
5.265282584 0.691464821 1.787197232 0.429065744 8.173010381 5.314878893 1.937716263
1.625720877 0.459630911 9.320645905 6.137254902 0.584198385 2.543829296 0.69088812
9.956170704 4.419261822 1.248558247 1.250288351 0.60438293 7.371395617 4.139561707
2.132064591 1.698385236 0.427912341 8.389273356 4.023068051 0.853517878 0.674163783
0.412918108 5.96366782
7 0 1 1 2 1 0.047526912 0.010623798 0.0444662 0.013797533 0.028718471
0.004249543 0.00900551 0.006452238 14.04005277 13.53994279 3.450725745 1.10236822
1.800016976 2.06094559 2.195059842 0.890077243 1.489177489 0.685714286 0.94915542
0.280451575 0 0.197266786 5.42733564 1.376297578 1.936851211 0.964532872 9.705017301
8.907439446 0.665224913 1.642733564 0.781141869 11.99653979 6.875432526 1.365051903
2.977508651 0.660899654 11.87889273 7.043252595 1.325259516 1.503460208 0.623702422
10.49567474 6.487889273 0.778546713 2.298442907 0.785467128 10.35034602 7.139273356
0.402249135 2.698096886 1.53200692 11.7716263 6.884083045 0.118512111 2.106401384
0.732698962 9.841695502 8.061418685 0.418685121 2.662629758 1.514705882 12.43252595
7.972318339 0.435121107 2.468858131 1.469723183 11.57612457 6.857266436 0.592560554
2.954152249 1.62283737 12.02681661 7.302768166 2.107266436 2.78200692 1.278546713
13.47058824
9 1 0 1 1 2 0.054761745 0.028595687 0.029204437 0.014806536 0.016688598
0.010026327 0.007575684 0.005221726 14.14607653 13.81604305 2.913674561 0.976063153
1.996095408 0.860198625 2.192343604 1.157117392 1.20091673 1.199643494 1.20091673
0.531364061 0.308123249 0.314234785 4.971741638 3.253171857 1.841407151 0.877739331
10.94405998 6.602076125 0.970011534 3.715974625 0.555074971 11.84313725 5.555940023
2.941176471 2.352941176 0.513264129 11.3633218 6.662629758 1.734717416 2.514417532
0.638985006 11.55074971 5.982122261 1.802768166 2.250288351 0.833333333 10.86851211
5.909457901 2.742214533 2.299307958 0.666666667 11.61764706 5.956170704 1.619953864
2.367358708 0.935409458 10.80968858 6.53633218 2.06343714 2.865051903 1.293540946
12.62572088 6.280853518 1.464244521 3.040369089 0.953863899 11.73875433 5.469146482
1.817474048 2.735294118 1.171568627 11.19925029 5.059400231 2.186851211 1.670703576
0.689734717 9.606689735
10 1 0 1 2 1 0.050611345 0.034688142 0.026722859 0.021409092 0.014422586
0.015322396 0.01517893 0.017774679 11.49384607 12.64829018 2.909600204 1.377132671
1.842458195 0.715898481 2.105593753 0.872930991 0.876496053 1.988031576 1.083269672
0.433070198 0.959171547 0.667855021 5.332756632 1.576124567 2.034602076 1.070357555
10.01384083 5.902537486 0.385813149 2.082468281 0.543829296 8.914648212 4.452133795

0.4544406 1.820645905 0.416955017 7.144175317 4.685121107 0.938869666 2.042675894
0.414071511 8.080738178 5.005767013 0.889273356 2.301614764 0.561130334 8.757785467
5.472318339 1.05449827 2.564302191 0.66349481 9.75461361 4.528258362 0.377739331
1.444059977 0.465397924 6.798154556 5.244521338 0.989042676 1.950980392 0.600346021
8.675317186 5.611880046 0.711649366 3.074971165 1.055363322 10.4538639 4.99538639
0.975201845 1.837370242 1.314878893 9.12283737 8.470011534 0.769896194 2.385813149
1.130334487 12.75605536
11 1 0 0 2 2 0.038695362 0.008346701 0.031313135 0.0059575 0.038350068
0.011465577 0.02193283 0.011455998 10.07233655 11.74505545 5.164502165 1.222307105
0.687717511 0.445463034 2.287411934 1.283252695 1.475681182 0.392920805 0.838808251
0.32730668 0.350394703 0.238010356 3.784602076 0.08650519 1.115051903 0.491349481
5.477508651 5.801038062 0.25 1.466262976 0.584775087 8.102076125 4.405709343 0.648788927
0.926470588 0.359861592 6.34083045 5.533737024 0.432525952 1.262110727 0.379757785
7.608131488 5.547577855 0.419550173 1.569204152 0.603806228 8.140138408 5.028546713
0.41349481 1.343425606 0.62283737 7.408304498 4.917820069 1.083044983 1.035467128
0.549307958 7.381487889 4.883217993 0.423875433 1.152249135 0.605536332 6.672145329
5.321799308 1.92733564 1.64532872 0.801038062 9.69550173 4.993079585 0.777681661
2.364186851 0.902249135 9.037197232 4.669550173 0.204152249 1.506055363 0.690311419
7.070069204
12 0 0 0 1 2 0.038058504 0.027802844 0.028286139 0.024072889 0.017741762
0.019651025 0.022362884 0.013631357 10.92527741 11.60283247 4.090909091 0.59714795
2.014090485 0.823189882 1.601731602 0.604532722 1.093710211 1.585943468 0.656650539
0.465665054 0.178592649 0.825736355 6.076701269 0.183967705 1.678777393 0.847750865
8.787197232 5.69550173 0.273356401 1.319492503 0.587081892 7.875432526 5.624567474
0.270472895 1.399653979 0.468858131 7.76355248 5.567474048 0.250288351 1.698961938
0.404267589 7.920991926 4.873702422 0.293540946 1.678777393 0.448096886 7.294117647
4.651095732 0.638985006 1.491349481 0.491349481 7.2727797 5.230103806 0.142445213
1.075547866 0.477508651 6.925605536 5.35467128 0.50461361 1.701845444 0.602652826
8.083044983 5.703575548 0.410611303 2.333333333 0.874855825 9.322376009 6.089388697
0.481545559 2.261822376 0.987312572 9.820069204 5.918685121 0.848904268 1.593425606
0.638985006 9
13 0 1 1 1 2 0.0254226 0.012365457 0.018988689 0.010230742 0.016824468
0.011146739 0.018973258 0.015435091 15.79181772 16.51676531 2.606315253 2.075375605
0.467192938 0.416942535 1.562855445 0.878363467 1.2179781 0.340208811 0.353790001
0.355996944 0.548680078 0.175027587 5.910034602 0.703575548 1.478662053 0.578431373
8.670703576 5.94982699 1.861014994 1.927912341 0.491349481 10.23010381 6.218569781
1.098615917 1.452710496 0.360438293 9.130334487 6.141868512 1.121107266 1.898500577
0.457900807 9.619377163 5.657439446 1.478085352 1.533448674 0.576701269 9.24567474
5.953575548 2.376009227 1.784025375 0.717128028 10.83073818 4.873125721 1.937716263
2.025951557 0.472318339 9.303344867 5.353517878 0.970588235 2.039792388 0.574394464
8.920991926 5.022491349 1.438292964 1.861591696 0.739331027 9.080161476 4.554209919
3.332179931 1.741637832 0.880622837 10.34832757 4.554209919 2.126874279 1.747404844
0.693194925 9.121683968
14 0 1 0 2 2 0.032307964 0.006108858 0.028245522 0.011274393 0.014363003
0.008575585 0.011843983 0.009902776 8.913713487 10.09143481 3.048892284 0.987522282
1.113487819 0.356336474 1.868941516 0.834394364 1.429590018 1.255411255 0.49163908
0.323232323 0.563279857 0.497411086 4.191464821 0.816608997 1.069204152 0.585928489
6.663206459 4.411188005 0.647635525 1.038638985 0.422145329 6.519607843 4.095155709
1.30449827 1.467704729 0.367358708 7.234717416 4.457900807 2.276239908 1.208765859
0.295847751 8.238754325 4.617647059 1.579008074 1.257208766 0.725490196 8.179354095
3.991926182 1.132641292 1.443483276 0.489042676 7.057093426 4.447520185 0.955594002
2.065167243 0.396770473 7.865051903 4.789504037 0.604959631 1.346597463 0.611880046
7.308535179 4.576701269 0.62283737 1.037485582 0.635524798 6.87716263 4.316608997
2.176470588 1.602076125 0.721453287 8.816608997 3.855247982 1.220299885 1.445790081

0.606113033 7.12745098
15 1 1 0 1 2 0.04216416 0.028441679 0.030547119 0.013603058 0.018757534
0.01027616 0.013468702 0.012214748 10.20325846 12.57873251 2.673287497 0.880315763
1.769629064 0.535777948 1.629063747 1.069688481 1.107715814 1.206773619 0.578049402
0.077582548 0.492487904 0.428656311 4.717128028 0.866782007 1.577854671 0.686851211
7.848615917 5.290657439 2.041522491 0.938581315 0.5 8.770761246 4.885813149 0.753460208
1.187716263 0.390138408 7.217128028 4.780276817 1.657439446 1.629757785 0.461937716
8.529411765 4.190311419 0.855536332 1.924740484 0.573529412 7.544117647 4.270761246
0.35899654 0.758650519 0.562283737 5.950692042 4.770761246 0.453287197 2.031141869
1.083044983 8.277681661 4.896193772 0.369377163 3.327854671 0.75432526 9.30449827
3.634083045 0.369377163 1.149653979 0.410899654 5.564013841 4.739619377 2.151384083
1.224913495 0.790657439 8.906574394 4.46366782 1.375432526 0.719723183 0.508650519
7.067474048
17 1 1 1 2 2 0.041963635 0.014225557 0.029656936 0.013552931 0.022474418
0.006868836 0.007230368 0.006150836 14.82938045 15.69536414 2.333842628 0 0.915202445
0.408454291 1.355912062 0.485697309 0.625159155 0.714795009 0.532212885 0.390968509
0.308462779 0.164502165 7.005190311 1.735870819 2.84083045 1.254901961 12.83679354
7.373414072 1.687139562 3.621683968 0.9544406 13.6366782 7.214532872 2.192041522
3.092848904 0.667820069 13.16724337 6.599192618 2.21799308 3.427912341 0.625720877
12.87081892 6.761822376 2.837370242 2.88177624 0.928489043 13.4094579 6.058823529
2.44982699 3.14071511 0.925605536 12.57497116 6.238754325 0.735870819 2.233564014
0.724913495 9.933102653 8.108419839 0.970588235 4.185121107 1.234140715 14.43483276
6.264705882 1.267877739 5.621972318 1.944348328 15.04267589 6.686851211 2.385813149
5.779123414 2.509803922 17.3615917 6.8411188 2.76384083 4.064878893 1.317474048
14.98731257
18 0 0 1 2 2 0.038406855 0.010369582 0.023970405 0.007225273 0.020403108
0.009185889 0.025930676 0.010793052 11.04247096 10.7094912 3.290807232 0.285459638
1.918003565 0.382819795 2.629148629 1.328410152 1.284441049 0.605551311 0.541040659
0.658517953 0.298955946 0 3.961361015 0.14994233 1.688581315 0.555940023 6.355824683
5.093425606 0.203575548 1.618800461 0.554209919 7.470011534 4.968858131 0.844867359
1.036908881 0.373702422 7.224336794 4.382929642 0.453863899 0.81372549 0.362168397
6.012687428 4.32295271 0.565743945 0.644752018 0.385813149 5.919261822 4.303344867
0.257208766 0.677623991 0.408304498 5.646482122 4.090542099 0.226643599 0.880046136
0.354094579 5.5455594 3.888696655 0.204152249 0.780853518 0.460207612 5.322376009
4.664359862 0.431372549 0.734717416 0.553056517 6.383506344 4.149365629 0.364475202
0.961361015 0.612456747 6.087658593 4.838523645 0.273356401 0.732987313 0.593425606
6.438292964
19 0 0 1 1 3 0.014845303 0.012499498 0.013633423 0.006447685 0.00770649
0.008434422 0.012360134 0.012953651 13.13969949 18.5273952 2.875273746 0.676954418
0.433749257 0.534250064 1.827009592 1.161701044 0.609116374 0.10236822 0.217638571
0.208131738 0.208810797 0.637806638 5.809688581 1.344290657 2.662629758 0.834775087
10.65138408 7.121972318 0.438581315 2.064878893 0.852941176 10.4783737 6.978373702
1.475778547 2.097750865 0.484429066 11.03633218 6.979238754 1.10467128 2.57266436
0.576124567 11.23269896 6.896193772 1.108131488 2.049307958 0.588235294 10.64186851
6.635813149 2.120242215 3.136678201 0.721453287 12.61418685 7.164359862 1.498269896
4.019031142 0.756920415 13.43858131 7.335640138 1.588235294 3.137543253 1.15916955
13.14273356 5.953287197 1.656574394 3.332179931 1.375432526 11.68858131 6.80017301
1.402249135 2.862456747 1.458477509 12.5233564 5.385813149 1.043252595 3.057958478
1.012110727 10.49913495
20 1 1 1 1 3 0.013298362 0.027453319 0.013572704 0.014325329 0.011342502
0.012300247 0.012051542 0.017287462 21.20650754 22.80513504 2.457601222 0.493251846 1.653509889
0.25244037 0.948306595 0.194211018 0.60758849 0 0.432560903 0.453102453 0.233766234
0.231729055 8.746828143 0.29527105 4.142445213 1.400807382 14.58535179 11.02941176 0.389273356
4.988465975 1.211072664 17.61822376 8.761245675 0.054786621 4.444636678 1.133794694 14.39446367

9.883506344 0.378892734 5.055940023 1.456747405 16.77508651 9.205882353 0.10438293 3.919838524
1.607843137 14.83794694 10.21683968 0.30911188 4.267589389 1.281430219 16.07497116 10.23154556
0.118800461 3.901960784 1.319492503 15.53143022 10.9106113 0.451557093 3.728373702 1.692618224
16.52941176 11.12975779 0.425028835 5.451557093 2.591695502 19.37024221 10.08823529 1.265282584
5.049596309 2.311995386 18.71510957 10.16089965 0.519607843 4.106689735 1.889273356 16.67647059
21 0 1 1 2 3 0.040226396 0.027878864 0.029820313 0.019095747 0.037863147 0.013336099
0.019754465 0.016678007 15.7097663 16.64573818 3.019438078 1.403955522 1.649605297 0.745267804
1.841303794 1.161531279 0.957728546 2.562006621 0.484508955 0.384008149 0.801459978 0.208810797
6.594290657 3.37283737 1.857266436 0.896193772 12.72058824 6.528546713 0.269896194 2.095155709
0.680795848 9.574394464 7.051903114 2.673875433 1.69982699 0.440311419 11.86591696 7.201557093
1.0683391 2.031141869 0.461937716 10.76297578 7.976643599 2.644463668 2.596020761 1.065743945
14.28287197 7.575259516 2.801038062 3.057958478 0.626297578 14.06055363 6.471453287 1.296712803
4.302768166 0.621107266 12.62283737 7.349480969 0.625432526 2.98615917 0.821799308 11.67906574
7.403979239 2.227508651 2.737889273 0.923875433 13.30709343 5.842560554 2.570934256 2.846020761
1.123702422 12.32785467 6.545847751 1.673875433 1.965397924 0.968858131 11.15397924
22 1 1 0 2 3 0.055614522 0.013585283 0.025822246 0.006005088 0.012817632 0.006621897
0.012092713 0.008995253 21.048261 23.19065511 3.438757321 0 2.382480265 0.399966047
2.774297598 0.627620745 1.268143621 0.424497072 0.555131143 0.356336474 0 0 6.957612457
3.69550173 4.89532872 1.410034602 16.95847751 10.7517301 1.666089965 5.064878893 1.538927336
19.0216263 8.256920415 3.433391003 4.719723183 0.813148789 17.22318339 10.28373702 2.363321799
7.467128028 1.091695502 21.20588235 9.076124567 2.934256055 6.125432526 1.044982699 19.18079585
7.594290657 4.936851211 6.155709343 1.176470588 19.8633218 7.899653979 3.019031142 4.623702422
0.929930796 16.43771626 9.32266436 0.589965398 4.530276817 1.333044983 15.72404844 9.970588235
1.525086505 8.546712803 1.916089965 22.09948097 8.428200692 2.576124567 7.110726644 1.810553633
19.83910035 6.203287197 1.168685121 5.935121107 1.060553633 14.36764706
23 1 0 0 1 3 0.030332168 0.010634386 0.033953002 0.015174912 0.018166644 0.015823883
0.013887935 0.010639316 10.61793878 11.77376687 3.811900518 2.193022664 1.559460148 0.726254138
1.756557168 0.785671844 0.998981411 0.620066208 1.185128597 1.164756812 0.72421696 0
7.366782007 0.143598616 0.506920415 0.942906574 8.960207612 7.520761246 0.140138408 0.636678201
0.548442907 8.846020761 8.153979239 0.188581315 1.283737024 0.520761246 10.14705882 8.041522491
0.302768166 1.487889273 0.439446367 10.2716263 6.487889273 0.461937716 0.870242215 0.577854671
8.397923875 7.813148789 0.846020761 2.299307958 0.697231834 11.65570934 7.884083045 0.088235294
1.948096886 0.638408304 10.55882353 6.303633218 0.12283737 2.026816609 0.728373702 9.147058824
6.856401384 0.05017301 2.65916955 0.901384083 10.46712803 4.778546713 0.546712803 0.788927336
0.676470588 6.790657439 6.501730104 0.173010381 1.1816609 0.792387543 8.648788927
24 0 1 0 1 3 0.02244402 0.017824127 0.014050984 0.009899638 0.00462185 0.011119272
0.002971117 0.005616039 15.40852125 18.86995473 3.127832951 0.727272727 3.247941601 0.642220525
2.044834904 0.907902555 1.620066208 0.280112045 1.570494865 0.903149138 0.391477803 0
7.416955017 0.60899654 5.075259516 1.35899654 14.46020761 6.868512111 0.666955017 5.113321799
0.752595156 13.40138408 6.863321799 1.371972318 3.950692042 0.833910035 13.01989619 7.253460208
1.494809689 4.955017301 1.40916955 15.11245675 7.293252595 2.55449827 4.051038062 2.134948097
16.03373702 10.84602076 2.25432526 7.134948097 1.556228374 21.79152249 7.717128028 1.148788927
6.824394464 1.338235294 17.02854671 7.655709343 0.337370242 6.293252595 1.979238754 15.57352941
7.450692042 0.937716263 6.524221453 2.238754325 17.15138408 7.692906574 0.954152249 7.807093426
2.522491349 18.9766436 6.348615917 1.824394464 4.841695502 1.897058824 14.91176471
26 0 0 0 2 3 0.027484978 0.00913327 0.021839981 0.008403275 0.030626183 0.007828025
0.011469772 0.007457956 15.73613893 13.69002009 2.441303794 0 1.474747475 0.81928529
1.408539173 0.964264494 1.556659027 0.197860963 0.551905611 0.548510313 0 0.29980477
8.192041522 0.423010381 3.185121107 1.247404844 13.04757785 9.441176471 0.32266436 2.364186851
0.753460208 12.88148789 9.191176471 0.567474048 2.272491349 0.664359862 12.69550173 9.285467128
0.430795848 1.966262976 0.631487889 12.31401384 8.301038062 0.452422145 2.598615917 0.85467128
12.2067474 11.76038062 0.62283737 4.156574394 1.035467128 17.57525952 7.855536332 0.165224913
1.997404844 0.602076125 10.62024221 7.522491349 0.198961938 1.493079585 0.900519031 9.942041522
7.311418685 0.288062284 0.973183391 0.788062284 9.360726644 5.367647059 0.484429066 1.500865052

0.742214533 8.095155709 8.570069204 0.517301038 1.214532872 0.878027682 11.1799308
27 1 0 1 2 3 0.034332175 0.020254015 0.026963403 0.016557761 0.009500131 0.016065836
0.01306544 0.011424402 14.57000366 13.56040622 2.560988032 0 1.350819116 0.733723793
1.719887955 0.525252525 0.723707665 1.426788897 0.413547237 0.326797386 0 0 7.837370242
1.026528258 0.961937716 1.369665513 11.19550173 9.388119954 0.521337947 2.27739331 1.16378316
13.35063437 7.621683968 0.350634371 1.493079585 0.655132641 10.12053057 8.275663206 1.017301038
1.521914648 0.599192618 11.41407151 6.950403691 1.012110727 1.403690888 0.955017301 10.32122261
5.987312572 1.044405998 2.15455594 1.031141869 10.21741638 8.071510957 0.776816609 2.761822376
1.34544406 12.955594 6.389273356 0.290080738 1.580161476 1.462802768 9.775951557 6.950980392
0.660322953 1.843713956 1.733564014 11.18858131 7.14071511 1.287485582 2.458189158 1.539792388
12.42618224 7.359861592 0.747404844 2.428489043 1.319492503 11.85524798
28 1 0 0 1 4 0.033324186 0.020246149 0.022553317 0.013514199 0.014977607 0.01468141
0.016333132 0.013790484 15.67481046 18.05237063 2.154570919 0.389355742 2.455818691 0.521347933
1.475426534 0.306086071 0.79908327 0.664374841 0.559714795 0 0 0 7.5 0.55017301
3.959630911 1.232987313 13.24279123 7.882352941 1.676470588 3.786620531 0.955594002 14.30103806
5.92733564 2.14994233 3.346020761 0.572087659 11.99538639 6.405420992 2.335063437 3.667243368
0.5911188 12.9988466 6.916378316 3.212226067 4.02710496 0.841983852 14.99769319 5.756632065
2.166666667 5.575547866 0.80449827 14.30334487 6.938869666 2.193194925 4.781430219 0.843713956
14.71107266 6.919261822 2.8183391 4.666666667 1.061707036 15.26989619 7.338811995 3.417820069
4.903114187 1.519031142 17.19953864 6.746828143 3.155132641 3.905420992 1.460207612 15.26758939
6.431372549 3.413206459 4.307093426 1.302191465 15.4538639
29 1 1 1 1 4 0.049991279 0.031874254 0.020422849 0.018116858 0.013491316 0.018465683
0.010244828 0.00838097 12.38920753 15.7293342 2.032085561 1.401578813 0.943722944 0.024615907
0.839317545 0.604872252 0.995925643 1.838298956 0.866819455 0.285544521 0.752058399 0
5.685121107 0.258362168 2.106113033 0.734140715 8.783737024 5.765282584 1.324682814 3.196655133
0.871395617 11.15801615 5.932525952 2.19550173 1.869088812 0.650519031 10.64763552 5.212802768
1.052479815 2.539792388 0.719723183 9.524798155 7.008650519 1.329873126 3.398500577 0.862745098
12.59976932 6.085351788 1.66378316 5.190311419 1.11361015 14.05305652 8.357554787 0.592272203
3.873702422 1.337370242 14.16089965 6.511245675 1.252018454 4.67704729 1.502595156 13.9083045
8.418685121 1.401384083 5.016724337 1.528258362 16.3650519 7.908304498 1.514417532 3.528835063
2.026528258 14.97808535 7.435986159 1.728373702 2.730680507 1.367935409 13.26297578
30 0 1 0 1 4 0.030476885 0.017733507 0.033397943 0.014460998 0.015512981 0.017699908
0.007088713 0.009622168 13.71682015 17.10313311 4.010949834 0.851031322 3.05118411 0.472625414
1.500721501 1.487310076 1.92793481 2.652915712 2.04074357 0.421865716 0.474323063 0.363296834
7.871972318 0.661476355 1.779123414 1.158016148 11.47058824 10.15628604 1.434832757 2.544982699
0.899653979 15.03575548 8.718569781 1.50461361 2.914071511 0.683391003 13.82064591 8.889273356
1.517301038 4.19550173 0.601499423 15.20357555 8.227797001 3.066320646 3.314302191 0.787773933
15.39619377 8.690311419 2.113033449 4.846597463 0.866205306 16.51614764 9.19088812 1.080161476
3.761245675 0.964821223 14.97404844 8.9544406 1.456170704 4.578431373 1.021337947 15.99769319
8.58650519 1.168973472 3.196078431 0.887543253 13.83910035 9.467128028 1.520472895 3.399365629
1.038062284 15.43252595 7.896770473 1.733564014 2.847174164 0.956747405 13.43425606
32 0 0 1 1 4 0.063457027 0.052389672 0.030112269 0.023158747 0.023566098 0.019356954
0.009624237 0.014156596 33.82866313 21.07006707 2.540870894 1.886681946 2.419489008 0.781257958
1.982004923 0.899414311 1.025974026 0.40565317 0.915202445 0.823529412 0 0 7.089965398
0.140138408 9.440311419 2.234429066 18.90484429 9.256920415 0.218858131 8.694636678 1.466262976
19.6366782 9.130622837 0.251730104 4.654844291 1.009515571 15.0467128 7.099480969 0.278546713
6.522491349 1.480968858 15.38148789 10.74307958 0.292387543 4.009515571 1.071799308 16.11678201
4.705017301 0.131487889 4.569204152 0.9316609 10.33737024 5.583910035 0.188581315 3.514705882
1.01816609 10.22750865 4.5 0.17733564 1.546712803 0.551903114 6.775951557 3.770761246
0.099480969 1.115916955 0.538062284 5.524221453 4.015570934 0.155709343 1.021626298 0.755190311
5.948096886 4.415224913 0.15916955 0.902249135 0.448096886 5.924740484
33 0 1 1 2 4 0.037900218 0.009980958 0.028733345 0.007382848 0.022415476 0.011060568
0.012800069 0.009905106 12.60189808 11.31764832 2.0710466 1.101349631 0.828452593 0.588914354
1.220609456 0.637297343 0.754978355 1.048943214 0.801799508 0 0 0 6.969723183 0.298442907

2.597750865 0.933391003 10.79930796 7.888408304 0.212802768 2.551038062 1.369377163 12.0216263
7.019896194 0.14100346 3.040657439 0.632352941 10.83391003 7.424740484 0.152249135 3.264705882
0.950692042 11.79238754 7.081314879 0.400519031 2.55017301 0.793252595 10.82525952 6.510380623
0.221453287 2.097750865 0.668685121 9.498269896 6.534602076 0.14532872 2.073529412 0.615916955
9.369377163 5.359861592 0.142733564 1.885813149 0.743079585 7.993079585 6.003460208 0.288927336
2.256920415 0.737889273 9.287197232 6.243944637 0.243079585 2.323529412 1.039792388 9.850346021
4.485294118 1.037197232 2.138408304 0.655709343 8.316608997
34 1 0 1 2 4 0.021039503 0.01626522 0.016788852 0.011959287 0.019645651 0.015787567
0.019755086 0.010197029 12.2679617 13.11120831 3.063661828 1.29004329 2.377557083 0.733554028
1.051014345 0.640522876 1.393175452 0.505984212 1.31024531 0.852898735 0 0 5.121107266
0.475201845 1.28200692 0.765859285 7.644175317 6.490196078 0.824106113 3.168973472 0.697231834
11.1805075 5.622260669 0.830449827 2.985582468 0.58650519 10.02479815 6.650519031 1.79527105
2.348327566 0.688581315 11.48269896 6.210495963 1.296424452 2.485005767 0.637831603 10.62975779
4.513264129 0.925605536 1.621107266 0.505190311 7.565167243 4.382352941 3.188004614 1.457324106
0.588235294 9.615916955 4.453863899 1.476355248 2.572087659 0.707035755 9.151672434 4.976931949
0.757208766 3.807958478 0.980968858 10.55651672 4.906574394 1.544982699 3.109573241 0.933679354
10.49480969 4.598039216 0.74567474 2.546712803 0.82295271 8.728950404
35 1 1 0 2 4 0.067882137 0.038378214 0.037052949 0.015501777 0.023220903 0.01385195
0.018650066 0.019720762 16.11090557 18.54678957 3.016806723 2.840845429 1.099397335 0.550547492
1.088532383 0.433239963 0.675324675 0.596553773 0.809948222 0.772939479 0 0 6.699538639
2.267589389 2.293540946 1.163206459 12.42387543 7.583621684 1.525951557 3.660899654 0.926758939
13.69723183 6.612456747 1.243367935 2.989042676 0.689158016 11.53402537 7.318915802 2.453863899
2.746828143 0.756632065 13.27623991 7.148788927 1.951557093 3.851787774 1.130334487 14.08246828
8.440599769 1.04094579 8.044982699 1.805651672 19.33217993 5.802768166 1.953863899 3.538062284
0.856401384 12.15109573 5.733564014 0.782583622 2.409457901 1.158592849 10.05420992 6.453863899
2.747404844 3.182237601 1.250865052 13.6343714 7.404267589 0.73644752 3.459630911 1.438292964
12.77912341 6.249134948 3.029988466 3.658592849 1.219723183 14.15743945
36 0 0 0 2 4 0.034610745 0.028550572 0.025694153 0.018537001 0.019386842 0.010594626
0.0129883 0.008907501 19.41963455 15.81899237 3.484593838 0 3.103132162 1.431117902
1.708174179 0.388252271 0.930990578 0.859943978 0.862745098 0.23223835 0 0 9.143598616
0.328719723 4.992214533 2.051903114 16.51643599 9.782871972 0.155709343 5.875432526 1.173875433
16.98788927 6.676470588 0.151384083 4.043252595 0.666089965 11.53719723 7.94550173 0.320069204
3.845155709 0.752595156 12.8633218 7.984429066 1.421280277 4.324394464 1.23183391 14.96193772
8.826124567 0.48615917 4.64100346 1.384948097 15.33823529 8.425605536 0.910899654 3.588235294
1.080449827 14.00519031 8.192906574 0.214532872 1.784602076 0.912629758 11.00432526 8.775951557
0.672145329 3.455017301 1.570069204 14.47318339 7.638408304 0.478373702 4.673010381 1.958477509
14.7482699 7.116782007 0.729238754 2.829584775 1.524221453 12.19982699