**Fig. 1** Effects of shade cover and nitrogen fertilization on plant carbon costs to acquire nitrogen in *G. hirsutum* (left panel) and *G. max* (right panel). Nitrogen fertilization treatments are represented on the x-axis. Shade cover treatments are represented through colored points and trendlines. Trendlines were created by back-transforming ~~marginal mean slopes and intercepts from species-specific linear mixed-effects models. These values were calculated using the ‘emtrends’ and ‘emmeans’ functions in the ‘emmeans’ R package (Lenth, 2019)~~ predicted marginal mean values across the range in x-axis values using the ‘emmeans’ function in the ‘emmeans’ R package (Lenth 2019). Specifically, carbon costs to acquire nitrogen were natural-log transformed for *G. hirsutum* and square root transformed in *G. max*. ~~These values were calculated using the ‘emtrends’ and ‘emmeans’ functions in the ‘emmeans’ R package (Lenth, 2019).~~ Points are jittered across the x-axis for visibility. Yellow points and trendlines represent the 0% shade cover treatment, blue points and trendlines represent the 30% shade cover treatment, green points and trendlines represent the 50% shade cover treatment, and purple points and trendlines represent the 80% shade cover treatment. Solid trendlines indicate slopes that are significantly different from zero (Tukey: P<0.05), while dashed trendlines indicate slopes that are not statistically different from zero.

**Fig. 2** Effects of shade cover and nitrogen fertilization on whole-plant nitrogen biomass in *G. hirsutum* (left panel) and *G. max* (right panel). Whole-plant nitrogen biomass is the denominator of the carbon cost to acquire nitrogen calculation. Nitrogen fertilization treatments are represented on the x-axis. Shade cover treatments are represented through colored points and trendlines. Trendlines were created by back-transforming ~~marginal mean slopes and intercepts from species-specific linear mixed-effects models. These values were calculated using the ‘emtrends’ and ‘emmeans’ functions in the ‘emmeans’ R package (Lenth, 2019)~~ predicted marginal mean values across the range in x-axis values using the ‘emmeans’ function in the ‘emmeans’ R package (Lenth 2019). Specifically, whole plant nitrogen biomass was natural-log transformed for *G. hirsutum* and square root transformed in *G. max*. ~~These values were calculated using the ‘emtrends’ and ‘emmeans’ functions in the ‘emmeans’ R package (Lenth, 2019).~~ Points are jittered across the x-axis for visibility. Yellow points and trendlines represent the 0% shade cover treatment, blue points and trendlines represent the 30% shade cover treatment, green points and trendlines represent the 50% shade cover treatment, and purple points and trendlines represent the 80% shade cover treatment. Solid trendlines indicate slopes that are significantly different from zero (Tukey: P<0.05), while dashed trendlines indicate slopes that are not statistically different from zero.

**Fig. 3** Effects of shade cover and nitrogen fertilization on root carbon biomass in *G. hirsutum* (left panel) and *G. max* (right panel). Root carbon biomass is the numerator of the carbon cost to acquire nitrogen calculation. Nitrogen fertilization treatments are represented on the x-axis. Shade cover treatments are represented through colored points and trendlines. Trendlines were created by back-transforming ~~marginal mean slopes and intercepts from species-specific linear mixed-effects models. These values were calculated using the ‘emtrends’ and ‘emmeans’ functions in the ‘emmeans’ R package (Lenth, 2019)~~ predicted marginal mean values across the range in x-axis values using the ‘emmeans’ function in the ‘emmeans’ R package (Lenth 2019). Specifically, root carbon biomass was square root transformed for both species. ~~These values were calculated using the ‘emtrends’ and ‘emmeans’ functions in the ‘emmeans’ R package (Lenth, 2019).~~ Points are jittered across the x-axis for visibility. Yellow points and trendlines represent the 0% shade cover treatment, blue points and trendlines represent the 30% shade cover treatment, green points and trendlines represent the 50% shade cover treatment, and purple points and trendlines represent the 80% shade cover treatment. Solid trendlines indicate slopes that are significantly different from zero (Tukey: P<0.05), while dashed trendlines indicate slopes that are not statistically different from zero.

**Fig. 4** Effects of shade cover and nitrogen fertilization on root nodule biomass (A) and the ratio of root nodule biomass to root biomass (B) in G. max. Nitrogen fertilization treatments are represented on the x-axis. Shade cover treatments are represented through colored points and trendlines. Trendlines were created by back-transforming ~~marginal mean slopes and intercepts from species-specific linear mixed-effects models. These values were calculated using the ‘emtrends’ and ‘emmeans’ functions in the ‘emmeans’ R package (Lenth, 2019)~~ predicted marginal mean values across the range in x-axis values using the ‘emmeans’ function in the ‘emmeans’ R package (Lenth 2019). Specifically, root nodule biomass and the ratio of root nodule biomass to root biomass were each square root transformed. ~~These values were calculated using the ‘emtrends’ and ‘emmeans’ functions in the ‘emmeans’ R package (Lenth, 2019).~~ Points are jittered across the x-axis for visibility. Yellow points and trendlines represent the 0% shade cover treatment, blue points and trendlines represent the 30% shade cover treatment, green points and trendlines represent the 50% shade cover treatment, and purple points and trendlines represent the 80% shade cover treatment. Solid trendlines indicate slopes that are significantly different from zero (Tukey: P<0.05), while dashed trendlines indicate slopes that are not statistically different from zero.