

Reference 18

Yu, Y; Stomph, TJ; Makowski, D; Zhang, LZ; van der Werf, W 2016 A meta-analysis of relative crop yields in cereal/legume mixtures suggests options for management *Field Crops Res.* 198, 269–279 10.1016/j.fcr.2016.08.001

Background and objective

Intercrops of cereals and legumes are grown worldwide, both in smallholder agriculture in developing countries and in organic farming systems in developed countries. The competitive balance between species is a key factor determining productivity in mixtures. Management factors, e.g. sowing time, sowing density and rate of N fertilizer, affect the relative competitiveness and performance of intercropped species. There is a need for an overarching analysis to elucidate general principles governing the relative performance of legumes and cereals in mixtures. Authors conducted a meta-analysis of published studies to explore how the relative yield of legumes and cereals in mixtures responds to relative sowing time, relative density and nitrogen fertilizer.

Search strategy and selection criteria

Data on yields in cereal/legume intercroppings used here are a sub-set of records from a database built by Yu et al. 2015 (Yu, Y., Stomph, T.-J., Makowski, D., van der Werf, W., 2015. Temporal niche differentiation increases the land equivalent ratio of annual intercroppings: a meta-analysis. *Field Crops Res.* 184, 133–144.). From the original database, all data records of cereal/legume intercroppings (552) were extracted, representing data from 144 experiments out of 77 publications. See Yu et al. 2015 (Yu, Y., Stomph, T.-J., Makowski, D., van der Werf, W., 2015. Temporal niche differentiation increases the land equivalent ratio of annual intercroppings: a meta-analysis. *Field Crops Res.* 184, 133–144).

Data and analysis

All analyses were conducted in R. Mixed effects models were fitted using the R function `lme` from the R package `nlme`. The assumption of equal variance for mixed effects models was checked by analyses of quantile plots and plots of residuals against fitted values. A negative correlation structure of data between the cereal and the legume from the same data record was added in the mixed effects models using the R function `corCompSymm` for the argument of correlation in `lme`. A non-linear model of the relationship between PLER of the cereals and PLER of the legumes was fitted to the data using the R function `gnls`. A comparison of goodness of fit between the linear mixed effects model (model 1) and the non-linear model (model 10) was conducted with Akaike information criterion. In this meta-analysis, authors did not use the inverse variance of LER as a weight since there were too few publications reporting measures of variance of yields.

Number of papers	Population	Intervention	Comparator	Outcome	Quality score
77	Cereals and legumes	Intercropping	Monoculture	Metric: Partial land equivalent ratio (PLER: the relative yield of an intercropped species compared to its yield in a sole crop); Effect size: Ratio of the considered metrics in the intervention to the considered metrics in the control	81.25

Results

- On average, intercroppings were more efficient in land use than sole crops (the median LER was 1.16, the mean 1.17 and the standard deviation 0.24, indicating substantial variation).

Factors influencing effect sizes

- Crop type : PLER of the cereals was greater than that of the legumes in ~75% of the cases (409 out of 552 cases) indicating that the competitiveness of cereals is normally higher than that of legumes in a mixture.
- Sowing time : Sowing a species earlier than its companion increased its relative yield.
- Crop density : An increase in density of a species increased its relative yield and decreased the relative yield of the companion species.
- Fertiliser application : The relative yield of cereals increased and that of legumes decreased with the amount of N fertilizer. The negative effect of N on the relative yield of legumes was mitigated if the legume was sown before the cereal.

Conclusion

The performance of cereals and legumes in an intercrop is affected by sowing densities, relative sowing times, and nitrogen fertilizer. These findings can be used to enhance species complementarity, total productivity and economic profit of intercropping.