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Intercropping for sustainability

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Intercropping for sustainability: Research developments and their application

A meta-analysis on weed suppression in annual intercropping

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Abstract

Weeds are a severe constraint for crop yield and quality. In arable crops, weeds are frequently controlled by herbicides, but these are costly to farmers and might have negative side-effects on health and the environment (WHO, 2019). Intercropping has for a long time been advocated as a potential practice for ecologically-based weed control (Liebman & Dyck, 1993). Numerous studies on weed suppression through intercropping have been conducted (Jamshidi *et al*., 2013; Campiglia *et al*., 2014). However, little work has been done to synthesize the findings in an overarching analysis. It is therefore unclear to what extent a weed suppressive effect can be achieved by intercropping, and how species choice, intercrop configuration and management factors influence this effect.

In this study, we therefore conducted a global meta-analysis to quantify the effects of two cash crop systems on weeds compared to the sole crops and to assess the influence of design and management factors on weed suppression (Gu *et al*., *submitted*). We focused on intercrops consisting of two annual crops that are both grown for their product. A total of 39 publications reporting 339 data records from 76 experiments were included in this study. Two effect sizes, R_{weak} and R_{strong}, were defined and reflect the ratio between the weed biomass in intercrops to that in pure stands of the least and the most suppressive crop species in the mixture, respectively. Five explanatory variables were used to describe effect sizes: species combination, intercropping design, intercropping spatial pattern, temporal niche differentiation and nitrogen fertilizer input. We used linear mixed effect models to estimate the mean effect sizes and explore relationships between effect sizes and explanatory variables (in R software) (R Core Team, 2014; Pinheiro *et al*., 2015). We identified the best random effect structure using Akaike's information criterion.

In general, weed biomass in intercrops was 58% lower than weed biomass in the least weed suppressive sole crop ($R_{weak} = 0.42$), while it was similar and not significantly greater than that in the more weed suppressive sole crop ($R_{strong} = 1.08$). The results indicated that intercrops consistently provide better weed control than the least competitive sole crops, while showing similar weed suppressive ability as the more strongly competitive sole crop. In maize/legume intercrops, maize was frequently the weaker competitor against weeds, while in small-grain cereal/legume intercrops, the legume species was frequently the poorest weed suppressor.

Intercropping design was divided into two groups based on relative density total (RDT), where RDT was defined as the sum of relative densities of both component species in intercrops (Yu *et al*., 2015). Intercrops in replacement design were those for which RDT = 1, whereas intercrops in additive design had an RDT>1. Results showed that intercrops with an additive design were generally better at suppressing weeds than intercrops in replacement design. Additionally, increased RDT significantly decreased R_{strong}. This observation is in line with the observation that crops at a higher plant density are generally more weed suppressive.

We distinguished three spatial patterns: mixed intercrops, alternate row intercrops and strip intercrops. When intercrops were using a replacement design, spatial arrangement was found to be important for improving weed suppression, as a mixed configuration would give better weed suppression than an alternate row configuration. However, when intercrops were using an additive design, spatial arrangement did not significantly affect the weed suppressive ability. Since distance between individual plants narrows with increasing plant density, this might explain why spatial configuration was found to be hardly important for weed suppression in additive intercrops.

Temporal niche differentiation (TND) was used to characterize the extent to which the component species in intercrops are complementary in growing period (Yu *et al*., 2015). We expected that a longer overlap in growing period between component crops would enhance the competitive level of intercrops to weeds. However, results showed that TND did not significantly affect the R_{weak} and R_{strong}. Similarly, for the effect of nitrogen fertilizer input, no significant effect on weed suppression was found in our meta-analysis. This result suggests that the N resource capture may not be the first critical competitive process affecting weeds in intercrops.

In summary, our findings confirm the general ability of intercropping to lift the weed suppressive ability to that of the stronger weed suppressive component crop. Intercropping design and spatial configuration were found to be the most influential explanatory variables: intercrops in additive design were generally better at suppressing weeds than intercrops in replacement design, whereas within replacement intercropping, a fully mixed design was more weed suppressive than an alternate row or strip design.

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