SINGLE-IMPACT FICHE
INTERCROPPING

IMPACT: PLANT NUTRIENT UPTAKE

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Note to the reader: This fiche summarises the effects of Intercropping on PLANT NUTRIENT UPTAKE. It is based on 5 synthesis papers[1], including from 17 to 132 primary studies.

1. WEIGHT OF THE EVIDENCE

CONSISTENCY OF THE IMPACT

Intercropping of multiple crop species (i.e., crop mixture cropping), as compared to monoculture, resulted in an overall positive effect on plant nutrient uptake (**Table 1**).

The table below shows the number of synthesis papers with statistical tests reporting i) a significant difference between the Intervention and the Comparator, that is to say, a significant statistical effect, which can be positive or negative; or ii) a non-statistically significant difference between the Intervention and the Comparator. In addition, we include, if any, the number of synthesis papers reporting relevant results but without statistical test of the effects. Details on the quality assessment of the synthesis papers can be found in the methodology section of this WIKI.

- crop mixture cropping: from a total of 6 results, 5 were positive and 1 showed a non-significant effect, as compared to monoculture.

Out of the 5 selected synthesis papers, 4 included studies conducted in Europe (see **Table 2**).

Table 1: Summary of effects. Number of synthesis papers reporting positive, negative or non-statistically significant effects on environmental and climate impacts. The number of synthesis papers reporting relevant results but without statistical test of the effects are also provided. When not all the synthesis papers reporting an effect are of high quality, the number of synthesis papers with a quality score of at least 50% is indicated in parentheses. The reference numbers of the synthesis papers reporting each of the effects are provided in **Table 3**. Some synthesis papers may report effects for more than one impact or more than one effect for the same impact.

				Statistically tested			Non-statistically tested
Impact	Metric	Intervention	Comparator	Significantly positive	Significantly negative	Non-significant	
Increase plant nutrient uptake	Nutrient uptake and use efficiency	Crop mixture cropping	monoculture	5	0	0	0

QUALITY OF THE SYNTHESIS PAPERS

The quality of each synthesis paper was assessed based on 16 criteria regarding three main aspects: 1) the literature search strategy and primary studies selection; 2) the statistical analysis conducted; and 3) the evaluation of potential bias. We assessed whether authors addressed and reported these criteria. Then, a quality score was calculated as the percentage of these 16 criteria properly addressed and reported in each synthesis paper. Details on quality criteria can be found in the methodology section of this WIKI.

2. IMPACTS

The main characteristics and results of the 5 synthesis papers are reported in **Table 2** with the terminology used in those papers, while **Table 3** shows the reference numbers of the synthesis papers reporting for each of the results shown in **Table 1**. Comprehensive information about the results reported in each synthesis paper, in particular about the modulation of effects by factors related to soil, climate and management practices, are provided in the **summaries of the synthesis papers** available in this WIKI.

Table 2: Main characteristics of the synthesis papers reporting effects on plant nutrient uptake. The references are ordered chronologically with the most recent publication date first.

Reference number	Population	Scale	Num. papers	Intervention	Comparator	Metric	Conclusion	Quality score
Ref2	Cereals and legumes	Global	17	Intercropping	Monoculture	Phosphorus use efficiency (Land equivalent ratio for P uptake, LERP; Net effect for P uptake, NEP)	Cereal/legume intercropping can increase the uptake of P and hence has the potential to increase P fertilizer use efficiency in agriculture.	75%
Ref4	Multiple crops	Global	132	Intercropping	Monoculture	Nitrogen fertilizer equivalent ratio (NFER) and phosphorus fertilizer equivalent ratio (PFER)	Intercropping saves nitrogen and phosphorus fertilizer compared with sole crop, offering opportunities for the sustainable intensification of both high- and low-input agriculture.	81%

[1] Synthesis research papers include either meta-analysis or systematic reviews with quantitative results. Details can be found in the methodology section of the WIKI.

Reference number	Population	Scale	Num. papers	Intervention	Comparator	Metric	Conclusion	Quality score
Ref6	Cereals and legumes	Global	29	Intercropping	Monoculture	Soil-derived N acquisition for intecrop legumes, cereals and legumes + cereals compared to monoculture	The meta-analysis confirms and highlights that intercropping consistently stimulates complementary N use between legumes and cereals by increasing N2 fixation by grain legumes and increasing soil N acquisition in cereals. Based on the results of this analysis it would be suggested that cropping systems diversification via intercropping can be used for simultaneous production of both cereals and grain legumes, while increasing the use of N-sources and reducing external inputs of N fertilizers, thereby enhancing the sustainability of agriculture.	88%
Ref7	Maize and soybean	Global	100	Intercropping	Monoculture	Nitrogen fertilizer equivalent ratio (FNER)	Exploiting species complementarities by intercropping maize and soybean enables major increases in land productivity with less fertilizer N use.	94%
Ref14	Cover crops: hairy vetch (Vicia villosa Roth)–cereal rye (Secale cereale L.)	United States	21	Intercropping	Monoculture	Nitrogen content in the aboveground biomass	Overall, the study suggests legume–grass mixtures, in this case hairy vetch–cereal rye, may provide greater agroecosystem services such as nitrogen retention and supply than either monoculture species accumulating as much nitrogen as pure hairy vetch.	75%

Table 3: Reference numbers of the synthesis papers reporting for each of the results shown in **Table 1**.

				Statistically tested			Non-statistically tested
Impact	Metric	Intervention	Comparator	Significantly positive	Significantly negative	Non-significant	
Increase plant nutrient uptake	Nutrient uptake and use efficiency	Crop mixture cropping	monoculture	Ref4, Ref6, Ref7, Ref14 and Ref2		Ref14	

3. FACTORS INFLUENCING THE EFFECTS ON PLANT NUTRIENT UPTAKE

Table 4: List of factors reported to significantly affect the size and/or direction of the effects on plant nutrient uptake, according to the synthesis papers reviewed.

Factor	Reference number
Crop/cultivar combinations	Ref4, Ref2 and Ref6
Fertiliser application	Ref2 and Ref6
Geographical area	Ref7
Growing degree days (climate)	Ref14
Method used to quantify Nitrogen fixation	Ref6
Previous crop	Ref14
Soil texture	Ref14
Sowing time	Ref7 and Ref2

4. KNOWLEDGE GAPS

Table 5: Knowledge gap(s) reported by the authors of the synthesis papers included in this review.

Ref Num	Gap
Ref4	Further research is needed to assess the environmental benefits of the high-input intercropping strategy compared with sole crops or reduced-input intercrops.
Ref7	Further research is needed to identify optimal combinations of planting configuration, sowing dates and fertilizer to achieve high yields and high N use efficiency in intercropping, and exploit biological N fixation without driving the system to very resource poor low yielding conditions.
Ref14	Future studies evaluating cover crop mixtures over monocultures should take into account of the multiple factors that influence mixtures productivity, including soil N availability and precipitation during cover crop growth period. Future studies should also prioritize research on belowground biomass and N accumulation with cover crop mixtures relative to monocultures.

5. SYNTHESIS PAPERS INCLUDED IN THE REVIEW

Table 6: List of synthesis papers included in this review. More details can be found in the summaries of the meta-analyses.

Ref Num	Author(s)	Year	Title	Journal	DOI
Ref2	Tang, XY; Zhang, CC; Yu, Y; Shen, JB; van der Werf, W; Zhang, FS	2021	Intercropping legumes and cereals increases phosphorus use efficiency; a meta-analysis	Plant Soil 460, 89–104	10.1007/s11104-020-04768-x
Ref4	Li, CJ; Hoffland, E; Kuyper, TW; Yu, Y; Zhang, CC; Li, HG;	2020	Syndromes of production in intercropping impact yield gains	Nat Plants 6, 653–	10.1038/s41477-020-0680-9

Ref Num	Author(s)	Year	Title	Journal	DOI
	Zhang, FS; van der Werf, W			660	
Ref6	Rodriguez, C; Carlsson, G; Englund, JE; Flohr, A; Pelzer, E; Jeuffroy, MH; Makowski, D; Jensen, ES	2020	Grain legume-cereal intercropping enhances the use of soil-derived and biologically fixed nitrogen in temperate agroecosystems. A meta-analysis	Eur J Agron 118, 126077	10.1016/j.eja.2020.126077
Ref7	Xu, Z; Li, CJ; Zhang, CC; Yu, Y; van der Werf, W; Zhang, FS	2020	Intercropping maize and soybean increases efficiency of land and fertilizer nitrogen use; A meta-analysis	Field Crops Res 246, 107661	10.1016/j.fcr.2019.107661
Ref14	Thapa, R; Poffenbarger, H; Tully, KL; Ackroyd, VJ; Kramer, M; Mirsky, SB	2018	Biomass Production and Nitrogen Accumulation by Hairy Vetch-Cereal Rye Mixtures: A Meta-Analysis	J Agron 91, 25–33	10.2134/agronj2017.09.0544

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