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Residual effects of intercrop system and rice as mono crop on growth and yield of maize in rice-based production system

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Abstract The plot previously planted with maize, peanut and sweet potato as intercropping system had higher organic matter, available phosphorus, exchangeable potassium, exchangeable magnesium extractable iron, manganese, zinc and copper, than the plot previously planted with rice as mono crop. The results suggested that intercropping system improved soil quality and might be beneficial to succeeding crops. Maize and rice grown after intercropping system were not significantly different for growth parameters, yield and yield components. Maize grown after intercropping system was better than its grown after rice because of higher yield (7,895 kg/ha and 8,558 kg/ha) for the plot after rice harvest and the plot after intercropping system. The results indicated that maize cultivation could be decreased in rice cultivation in irrigated areas of the dry season. It is possible the rice growers can select both systems.

Keywords: Intercropping system, Monocropping system, Off-season, Maize

Introduction

If the new systems are comparable to the old systems, intercropping systems in crop rotation production systems might be effective and productive to reduce rice (*Oryza sativa*) production in the irrigated areas in which rice is produced as a sole crop in all seasons for decades. In Thailand and other Asian countries, rice is a staple food and it is produced under rainfed and irrigated conditions. Under rainfed condition, the soil in the lowland areas is left fallow after rice harvest in the long drought period, and it has very limit chances to produce other crops and use other cropping systems because it is under waterlogging condition in the rainy season. Under irrigated condition in contrast, the farmers have many options to produce crops if the new systems are more incentive than the old one.

Thailand has long been the first rank for rice exporters. Under the current situation, the country faces the difficulty to hold the same position because other countries increase rice production and the completion in the

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international rice market is high. Furthermore, Thailand, like most countries in the world, has encountered water problem such as drought for example. Drought problem becomes more severe for rice production under irrigated condition because of the limited resources and competition for water from other sectors such as industry and urban consumption.

Thai government has devised the policy to reduce rice production especially in irrigated areas by growing other crops. However, the rice growers are reluctant to adopt the policy and the reduction in rice production area has not been successful because the lack of the suitable production systems to convince the rice growers to change their system. Intercropping systems in crop rotation production systems might be the alternative systems to reduce rice productions.

Rice can be replaced by other crops in rotation in different seasons (Kombiok *et al*. 2012), and two or more types of crops can be grown simultaneously in the same plot of land in the same season using different cropping patterns (Eskandari *et al*. 2009; Marenco and Santos, 1999). The advantages of crop rotation over mono crop production system are weed reduction (Marenco and Santos, 1999; Gbanguba *et al*., 2011), pest reduction (Bullock, 1992; Ball *et al*., 2005; Kombiok *et al*. 2012) and reduction for the risk of crop failure (Rusinamhodzi *et al*., 2012). In infertile soils, intercropping systems could increase yield especially for legumes that can fix nitrogen (Kermah *et al*., 2017; Thierfelder *et al*. (2012). It seems likely that growing some more crop species in the same time or in rotation in different seasons is more promising than growing sole crop.

In Thailand, rice and rubber are the problematic crops for their excess supply and price slump, and their production areas need to be reduced. Sugarcane, cassava and maize are better for their price stability, and, in some years, the growers can enjoy the high price. The production areas of these crops can be expanded for some extent. Therefore, the adjustment of agricultural structure of the country is the important policy of the government. Of these promising crops, sugarcane and cassava can substitute the areas for upland rice because they are more perennial and cannot withstand waterlogging, and maize is more suitable for irrigated areas in the dry season because it is an upland annual crop that uses less water than rice.

Maize was then selected to be planted after rice harvest and the harvest of intercrops consisting of maize (*Zea mays* L.), peanut (*Arachis hypogaea* L.) and sweet potato (*Ipomoea batatas*) planted in a strip patterns. Maize crops from the two plots were then compared for growth and yield. The soils were also analyzed for soil properties prior to planting of the succeeding crop. The assumptions for this study are that maize crops in both plots should produce acceptable yield for the farmers because of the advantages of crop rotation, and intercropping system should be better than mono cropping system for providing better soil quality because it includes more crop species especially for legume crop that can fix nitrogen. The objectives of this study were to compare soil properties of the plots after harvest of rice as mono crop and the crops grown in intercropping system and to investigate growth and yield of the maize grown on this plots in the dry season under furrow irrigation. The information obtained in this study is important for convincing the rice growers to grow other crops in the dry season to reduce rice production in the irrigated areas.

Materials and methods

Location

The experiment was conducted in the farmer's field in Mueang District, Phichit province (N 16˚28.600 E 100˚15.416), Thailand. The field was divided into two plots. One plot with the area of 0.21 ha was previously used for a strip intercropping system consisting of maize, peanut and sweet potato and another plot with the area of 0.62 ha was planted with rice as mono crop. In the following season, maize was then planted in both plots as a succeeding crop.

Planting and cultural practices

Conventional tillage was practiced for soil preparation, and incorporation of crop residues into the soil. Chemical fertilizer (formula 15-15-15 of N-P-K) at the rate of 156 kg/ha was incorporated into the soil during soil preparation. Raised beds with the size of 150 cm including a small furrow for each bed were constructed in both plots.

Maize was planted on the raised beds (double-row beds) with a spacing of 75 × 25 cm at a rate of 1-3 seeds per hill using a tractor-powered planting machine on June 5, 2018. The seedlings were thinned to obtain one plant per hill at 7 days after planting (DAP). Urea fertilizer (46-0-0) at a rate of 250 kg/ha and chemical fertilizer (formula15-15-15) at a rate of 156 kg/ha were also applied at 30 DAP. Water as applied to the crop by a furrow irrigation system at 7-10 day intervals until crop maturity. Other crop management practices including weed and pest controls were done uniformly by the farmer.

Soil and plant data collection

The plot previously planted with maize, peanut and sweet potato was divided into 560 grids each of which had the area of 2 × 2 m, and the plot previously planted with rice was divided into 200 grids each of which had 6 × 6 m. Soil and plant data were then taken from the grids, which were selected randomly at the intensity of 10% in both plots, accounting for 14 and 20 grids for the first plot (previously planted with maize, peanut and sweet potato) and the second plot (previously planted with rice), respectively (Figure 1).

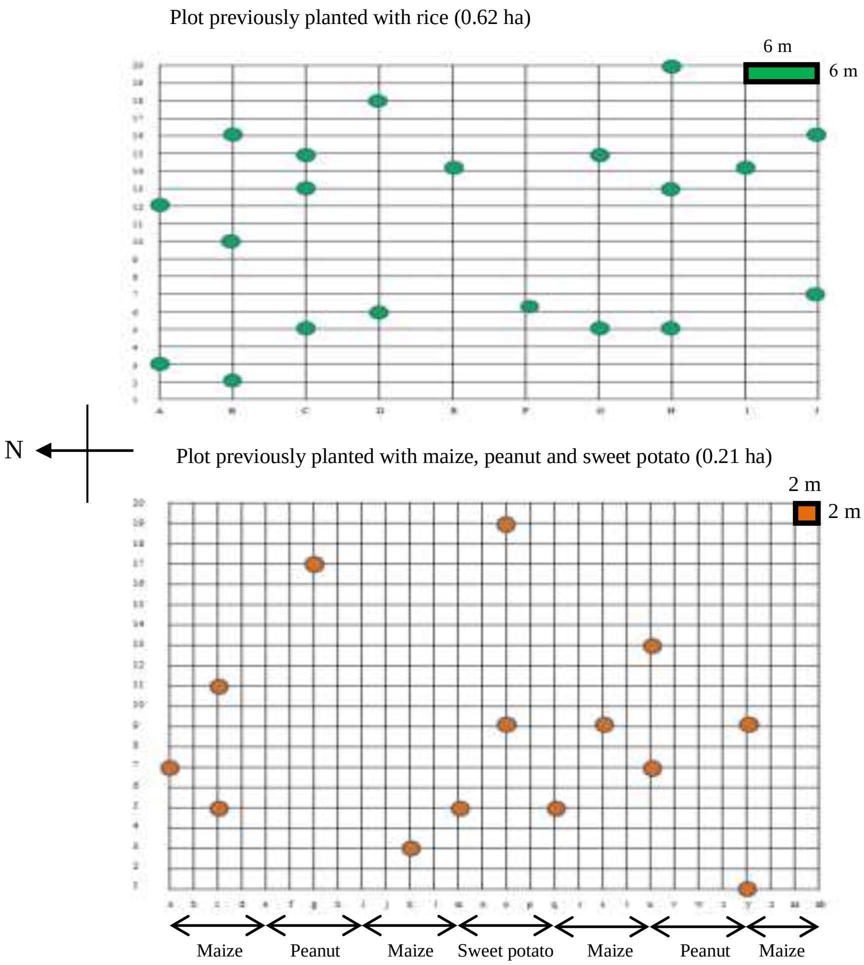

Figure 1. Schematic images showing the grids for plant sampling for the plot previously planted with rice (above) and the plot previously planted with maize, peanut and sweet potato (below)

Soil was collected from the field at the depth of 0-30 cm from the soil surface after incorporation of crop residues into the soil prior to fertilizer application. Soil samples were analyzed for soil chemical properties including organic matter (OM), soil pH, electrical conductivity (EC), available phosphorus (P), exchangeable potassium (K), exchangeable calcium (Ca) exchangeable magnesium (Mg), exchangeable sodium (Na), extractable iron (Fe), extractable manganese (Mn), extractable zinc (Zn) and extractable copper (Cu). OM was determined by a method reported by Walkley and Black (1934). Soil pH (soil:water, 1:1) was determined by a pH meter (BT-10). EC (soil:water, 1:5) was determined by a method reported by Richards (1954).

P was determined by a colorimetric method after the soil was extracted for phosphorus content by a Bray II method (Bray and Kurtz, 1945). K, Ca, Mg and Na were extracted with 1*N* ammonium acetate at pH 7.0, and the values were then determined by an inductively coupled plasma optical emission spectrophotometry (ICP-OES) (optima 4300 dv) (Spark *et al*., 1996). Fe, Mn, Zn and Cu were extracted with Diethylenetriaminepentaacetic acid (DTPA pH 7.3) (Lindsay and Norvell, 1978) and then determined by an ICP-OES (Spark *et al*., 1996).

The data were recorded for plant height in the field prior to harvest. At harvest, leaves, stems and husked ears were separated and oven-dried at 80 ℃ for 48 hours or until their dry weight was constant. Then, the leaf dry weight, stem dry weight, husked ear dry weight were measured. Unhusked ear weight was recorded after removing husk from the ears. The number of rows per ear and number of kernels per row were counted. Ear length, ear diameter, kernel depth, 1000-kernel weight and kernel dry weight were measured.

The means for soil properties and plant parameters of the plots were compared by a nonpooled *t-test* method because of the different numbers of plants sampled from the intercropping (14 grids) and monocropping (20 grids) system plots. In practice, the means were found with an M-STATC program from Michigan State University (Bricker, 1989).

Results

Soil chemical property

Intercropping system had higher properties than rice as a mono crop for most parameters except for exchangeable calcium in which the increase was negative (-2.0%) (Table 1). It is interesting to note here that calcium was the highest nutrient (1,111.33 mg/kg for rice and 1,089.13 mg/kg for intercropping system) compare to other nutrients. However, the differences between intercropping system and mono cropping system were not significant for most soil chemical properties except for pH, organic matter, available potassium, extractable magnesium, extractable zinc and extractable copper ($P \leq 0.01$).

Growing intercrops as a previous crop resulted in the significant increase in pH of 6.7% (from 5.11 to 5.45) compared to rice. Growing intercrops significantly increased organic matter of 12.3% and available phosphorus of 128.3%, which was highest. Organic matter values in this study were intermediate (2.53% for rice and 2.84% for intercropping system), whereas available phosphorus values were 15.82 mg/kg for rice and 36.12 mg/kg for intercropping system.

It is also interesting to note here that growing intercrops also significantly increased three micro nutrients including extractable magnesium, extractable zinc and extractable copper. Growing intercrops increased extractable manganese of 65.2% (32.12 mg/kg for rice and 53.07 mg/kg for intercropping system), extractable zinc of 37.0% (1.54 mg/kg for rice and 2.11 mg/kg for intercropping system) and extractable copper of 17.8% (2.81 mg/kg for rice and 3.31 mg/kg for intercropping system).

Table 1. Means for soil chemical properties of the plots previously planted with rice as a mono crop and intercrops consisting of maize, peanut and sweet potato planted in a strip pattern as previous crops and maize as a succeeding crop in rice-based production systems

Soil property	**Previous cropping system**		***t-test***	**% increase**
	Rice as mono crop	**Intercropping**		
pH	5.11	5.45	**	6.7
EC (μS/cm)	90.31	111.36	ns	23.3
OM (%)	2.53	2.84	**	12.3
Available P (mg/kg)	15.82	36.12	**	128.3
Exchangeable K (mg/kg)	51.54	71.40	ns	38.5
Exchangeable Ca (mg/kg)	1,111.33	1,089.13	ns	-2.0
Exchangeable Na (mg/kg)	36.74	57.79	ns	57.3
Exchangeable Mg (mg/kg)	211.73	224.90	ns	6.2
Extractable Fe (mg/kg)	215.87	226.86	ns	5.1
Extractable Mn (mg/kg)	32.12	53.07	**	65.2
Extractable Zn (mg/kg)	1.54	2.11	**	37.0
Extractable Cu (mg/kg)	2.81	3.31	**	17.8

ns, ** = not significantly different and significantly different at $P \leq 0.01$, respectively, by non-pooled *t-test*

Growth of maize

Maize was planted as a succeeding crop after intercropping system and mono cropping system (rice), and growth parameters were presented in Table 2. Maize crops grown after intercropping system and mono cropping system were not significantly different for total dry weight, leaf dry weight, stem dry weight and husked ear weight. Although they were not significantly different, Maize crop grown after intercropping system was higher than that grown after rice for all growth parameters, accounting for 10.1, 7.6, 13.6 and 9.4% for total dry weight, leaf dry weight, stem dry weight and husked ear weight, respectively. The results indicated that intercropping system was superior to mono cropping system for growth parameters of succeeding maize.

Yield and yield component of maize

Maize crops grown after intercropping system and mono cropping system were not significantly different for unhusked ear weight, cob weight, kernel weight (grain yield), ear length, ear diameter, number of kernel rows per ear, number of kernels per ear and 1000-kernel weight (kernel size) (Table 2). Although they were not significantly different, maize crop grown after intercropping system increased all these parameters compared to that grown after mono cropping system, and the percent increases ranged from 1.9 to 8.8%. The results pointed out that intercropping system might be superior to mono cropping system (rice) for yield and yield components of maize grown as succeeding crop.

Table 2. Means for total dry weight, leaf dry weight, stem dry weight, husked ear weight, unhusked ear weight, cop weight, kernel weight, cob length, ear diameter, number of rows per ear, number of kernels per ear, kernel depth and 1000-kernel weight of maize grown as a succeeding crop after intercropping system and mono cropping system (rice) in rice-based production systems

Growth and yield	Mono cropping	Inter cropping	*t-test*	% increase
Total dry weight (kg/ha)	15,790	17,381	ns	10.1
Leaf dry weight (kg/ha)	2,391	2,573	ns	7.6
Stem dry weight (kg/ha)	3,530	4,010	ns	13.6
Husked ear weight (kg/ha)	9,868	10,798	ns	9.4
Unhusked ear weight (kg/ha)	883	1,054	ns	19.3
Cob weight (kg/ha)	1,090	1,185	ns	8.8
Kernel weight (kg/ha)	7,895	8,558	ns	8.4
Ear length (cm)	18.0	18.4	ns	2.3
Ear diameter (cm)	4.6	4.7	ns	2.5
Number of rows per ear	16.1	16.8	ns	4.3
Number of kernels per row	36.8	37.5	ns	1.9
Kernel depth (mm)	10.9	11.3	ns	4.2
1000 kernel weight (g)	266.4	271.4	ns	1.9

ns = not significantly different at $P \leq 0.05$ by nonpooled *t-test*

Discussion

The assumptions underlying the research project are that maize crops in both plots should produce acceptable yield for the farmers because of the advantages of crop rotation, and intercropping system should be better than mono cropping system for providing better soil quality. In this study, intercropping system improved most soil chemical properties compared to the soil after rice harvest although significant differences were found for some parameters such as soil pH, organic matter, available phosphorus, extractable manganese, extractable zinc and extractable copper. However, soil differences were not strong enough to cause significant differences for growth parameters, yield and yield components of maize although most crop parameters had the increasing trends. The results supported our assumptions for soil quality, but the results were still not clear for crop performance. The similarity in crop performance between two plots would be due to the effects of several uncontrollable factors such as fertilizer application, weed and pest that could cancel out the small effects of soil differences.

In previous studies, the benefits of growing different crop species in the same time in the plot and in sequence of crop rotation in different seasons were due to lower weed (Gbanguba *et al*., 2011) and pest (Kombiok *et al*., 2012) infestation in the succeeding crop. In this study, the farmers also applied chemical fertilizers to the crop at high rate and the effects of applied fertilizers may be greater than the residual fertilizers. The comparison with non-fertilized plot might elucidate the results, but, unfortunately, the plots were not available in commercial maize production in this study.

Maize grain yields of 7,895 kg/ha and 8,558 kg/ha for the plot after rice harvest and the plot after intercropping system were normal for commercial production of maize under irrigation. The yields of both plots were convincing, and the farmers can adopt both systems to reduce rice production.

The positive effect of pulse legumes on succeeding crops have been studies in many legume species. The effects may be in question for some species if seed is harvested and removed from the fields. However, many pulse legumes can exploit nitrogen fixation and the fixed nitrogen is available for succeeding crops although the seed is removed from the fields. In previous study, peanut is the kind of this type (Schmidt and Frey, 1992; Toomsan *et al*., 1995). Pulse legumes are the candidates for cropping systems aiming to improve soil quality and to provide additional income. Other pulse legumes that can provide fixed nitrogen for succeeding crops although seed is harvested and remove from the fields include pigeon pea (Mathews *et al*., 2001; Marer *et al*., 2007), faba bean (Li *et al*., 2003; Li *et al*., 2007) and cowpea (Senaratne *et al*., 1995).

The increases in soil nutrients in intercrop plot would be possibly due to the effect of peanut haulm rather than maize residue and sweet potato residue. The increase in phosphorous bioavailability was observed in maize intercropped with faba bean (Li *et al*., 2003; Li *et al*., 2007; Latati *et al*., 2016) According to Latati *et al*. (2016), nitrogen fixation process also increased soil pH. The increase in soil pH was also observed in soil planted with velvet beans (Ortiz-Ceballos *et al*., 2015), and the increase in soil pH resulted in the increase in phosphorus release (Li *et al*., 2007).

According to Ali *et al*. (2009), the current maize hybrids consumed more fertilizers than other traditional cereal crops, and, because of its high yielding, the income from maize would be higher. Maize also has fewer pest and disease problems. When other benefits such as reduction in the risk of crop failure, reduction in water use are considered, growing maize for both in rotation or in combination with other crop species to replace rice in the dry season can be recommended to the rice growers.

However, care must be taken to extrapolate the results to other systems because the study was limited to one season, and additional studies are still required to confirm the results. The disadvantages of maize compared to rice are that additional irrigation management is still required and the crop requires higher investment in fertilizers to obtain acceptable yield. In this case, access to credit and other subsidy schemes might solve the problem.

The study answered to the questions whether maize can be produced successfully in rotation with rice in rice-based production system both after rice and after intercropping system under irrigation. The results pointed out that both systems can be adopted to reduce rice production. The information is important for the extension personnel to provide advises to the farmers.

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References

Ali, M. Y., Waddington, S. R., Hodson, D., Timsina, J. and Dixon, J. (2009). Maize-rice cropping systems in Bangladesh: Status and research opportunities. Journal of Agricultural Science and Technology, 3:35-53.

Ball, B. C., Bingham, I., Rees, R. M., Watson, C. A. and Litterick, A. (2005). The role of crop rotations in determining soil structure and crop growth conditions. Canadian Journal of Soil Science, 85:557-577.

Bray, R. H. and Kurtz, L. T. (1945). Determination of total organic and available forms of phosphorus in soil. Soil Science, 59:39-45.

Bricker, A. A. (1989). MSTAT-C User's Guide. Michigan State University, East Lansing, MI.

Bullock, D. G. (1992) Crop rotation. Critical Reviews in Plant Sciences, 11:309-326.

Eskandari, H., Ghanbari, A. and Javanmard, A. (2009). Intercropping of cereals and legumes for forage production. Notulae Scientia Biologicae, 1:07-13.

Gbanguba, A. U., Ismaila, U., Kolo, M. G. M. and Umar, A. (2011). Effect of cassava/legumes intercrop before rice on weed dynamics and rice grain yield at Badeggi, Nigeria. African Journal of Plant Science, 5:264-267.

Kermah, M., Franke, A. C., Adjei-Nsiah, S., Ahiador, B. D. K., Abaidoo, R. C. and Giller, K. E. (2017). Maize-grain legume intercropping for enhanced resource use efficiency and crop productivity in the Guinea savanna of northern Ghana. Field Crops Research, 213:38-50.

Kombiok, J. M., Buah, S. S. J. and Sogbedji, J. M. (2012). Enhancing soil fertility for cereal crop production through biological practices and the integration of organic and inorganic fertilisers in northern savanna zone of Ghana. Intech online publishers.

Latati, M., Bargaz, A., Belarbi, B., Lazali, M., Benlahrech, S., Tellah, S., Kaci, G., Drevon, J. J. and Ounane, S. M. (2016). The intercropping common bean with maize improves the rhizobial efficiency, resource use and grain yield under low phosphorus availability. European Journal of Agronomy, 72:80-90.

Li L., Zhang, F. S., Li, X. L., Christie, P., Yang, S. C. and Tang, C. (2003). Interspecific facilitation of nutrient uptake by intercropped maize and faba bean. Nutrient Cycling in Agroecosystems, 65:61-71.

Li L., Li, S. M., Sun, J. H., Zhou, L. L., Bao, X. G., Zhang, H. G. and Zhang, F. S. (2007). Diversity enhances agricultural productivity via rhizosphere phosphorus facilitation on phosphorus-deficient soils. Proceedings of the National Academy of Sciences, USA, 104:11192-11196.

Lindsay, W. L. and Norvell, W. A. (1978). Development of a DTPA soil test for zinc, iron, manganese and copper. Soil Science Society of America Journal, 42:421-428.

Marenco, R. A. and Santos, A. M. B. (1999). Crop rotation reduces weed competition and increases chlorophyll concentration and yield of rice. Pesquisa Agropecuaria Brasileira, 34:1881-1887.

Marer, S. B., Lingaraju, B. S. and Shashidhara, G. B. (2007). Productivity and economics of maize and pigeonpea intercropping under rainfed condition in northern transitional zone of Karnataka. Karnataka Journal of Agricultural Science, 20:1-3.

Mathews, C., Jones, R. B. and Saxena, K. B. (2001). Maize and pigeonpea intercropping systems in Mpumulanga, South Africa. International Chickpea and Pigeonpea Newsletter, 8:53.

Ortiz-Ceballos, A. I., Aguirre-Rivera, J. R., Salgado-Garcia, S. and Ortiz-Ceballos, G. (2015). Maize- velvet bean rotation in summer and winter milpas: a greener technology. Agronomy Journal, 107:1:330-336.

Richards, L. A. (1954). Diagnosis and Improvement of Saline and Alkali Soil. USDA Agriculture. Handbook 60. Washington, D. C.

Rusinamhodzi, L., Corbeels, M., Nyamangara, J. and Giller, K. E. (2012). Maize–grain legume intercropping is an attractive option for ecological intensification that reduces climatic risk for smallholder farmers in central Mozambique. Field Crops Research, 136:12-22.

Schmidt, G. and Frey, E. (1992). Cropping systems research at the Nyankpala Agricultural Experiment Station. In Improving farming systems in the interior savanna zone of Ghana. Acquaye and NAES (ed.), pp. 14-35.

Senaratne, R., Liyanage, N. D. L. and Soper, R. J. (1995). Nitrogen fixation of and N transfer from cowpea, mungbean and groundnut when intercropped with maize. Fertilizer research, 40:41-48.

Sparks, D. L., Page, A. L., Helmke, P. A., Loeppert, R. H., Soltanpour, P. N., Tabatabai, M. A., Johnston, C. T. and Summer, M. E. (1996). Lithium, sodium, potassium, rubidium, and cesium. Bertels, J. M. editor, Method of soil analysis part 3 chemical methods, Medison Soil Science Society of America, pp.551-574.

Thierfelder, C., Cheesman, S. and Rusinamhodzi, L. (2012). A comparative analysis of conservation agriculture systems: Benefits and challenges of rotations and intercropping in Zimbabwe. Field Crops Research, 137:237-250.

Toomsan, B., McDonagh, J. F., Limpinuntana, V. and Giller, K. E. (1995). Nitrogen fixation by groundnut and soyabean and residual nitrogen benefits to rice in farmers' fields in Northeast Thailand. Plant and Soil, 175:45-56.

Walkley, A. and Black, C. A. (1934). An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chronic acid titration method. Soil Science, 37:29-37.

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