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Does Intercropping of Baby Corn (*Zea mays* L.) with Pulse Legumes Improve Soil Fertility, Crop Productivity and Profitability?

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ABSTRACT

Purpose : *Intercropping of baby corn (Zea mays L.) with pulse legumes might improve production efficiency and increase profitability. The objectives of this study were to compare growth, yield and nitrogen uptake of baby corn and pulse legumes in intercropping systems and to determine income from the systems.*

Research Method : *Four treatments consisting of baby corn alone, baby corn with mungbean (Vigna radiata (L.) Wilczek), baby corn with soybean (Glycine max) and baby corn with crawling cowpea (Vigna unquiculata L. Walp) were assigned in a randomized complete block design with three replications.*

Findings : *All intercropping systems reduced growth and yield of baby corn and the income from the legumes could not reimburse for crop loss. Crawling cowpea was the best legume for intercropping system in term of providing better crop residue for succeeding crops. Among three pulse legumes investigated, cowpea had the highest nitrogen uptake, and its residue may be beneficial to succeeding crops. The reasons for reduction in baby corn yield and the alternative means for intercropping to increase income are discussed.*

Originality : *Intercropping system is generally practiced to increase crop production efficiency. In this study, intercropping baby corn with pulse legumes did not increase income for baby corn growers because baby corn had the highest market price and pulse legumes reduced yield of baby corn.*

Keywords: *husked ear yield, income, nitrogen fixation, production efficiency*

INTRODUCTION

Baby corn (*Zea mays* L.) is an important type of corn as its young cobs are consumed as vegetable worldwide (Manea *et al*., 2015). In Thailand, it is important as fresh vegetable for local consumption and processed baby corn for export (Subhadrabandhu and Wongwanich, 1996). The young cobs are harvested as immature stage, when the kernels are not produced on the cobs. Baby corn is consumed as a fresh vegetable or cooked vegetable and used as an ingredient in a wide variety of food recipes.

As an industrial crop for canned baby corn, the use of good varieties is a must for high quality products and the varieties should be of early maturity with about 50 days to harvest and male sterility to reduce labour cost for de-tasselling and increase yield (Kasetsart University Research and Development Institute, 2019). The earlier varieties in Thailand are not male sterile and de-tasselling is necessary for baby corn production and the practice, although it improves baby corn quality, and is laborious and also causes yield reduction. The institute developed a male sterile variety named Kasetsart 3 to replace the earlier varieties. The newly-developed variety has been well-accepted by baby corn growers and the baby corn processing industry.

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The use of the new variety with male sterility could improve corn production, productivity and profitability of baby corn growers. However, baby corn is said to be a greedy crop for nutrients especially for nitrogen and phosphorus, while potassium is sufficient for baby corn in most growing areas in the country. Therefore, high dosage of nitrogen fertilizer is applied to the crop, leading to the depletion of soil nutrients and low crop productivity in long term production.

Fertilizer in the forms of organic and inorganic is the most effective means to increase crop productivity (Jaja and Barber, 2017). According to the law of minimum, crop yield is limited by deficiency of some elements although other elements are sufficient (Velayutham, 2017). Fertilizers from organic sources in the forms of manure and compost are used to improve nutrient balance and physical properties of the soils (Timsina, 2018). However, the application of organic fertilizers is limited due to the unavailability of fertilizers, high cost and low macro nutrients. The application of organic fertilizers incurs an extra cost of production.

Legume crops are known as nitrogen fixing crops that transform atmospheric nitrogen into mineral nitrogen available to the crops (Kermaha *et al*., 2018). Fixed nitrogen is used for growth and yield of the crops and also available for the succeeding crops (Adeleke and Haruna, 2012). Legume crops can be used as green manure, cover crops and economic crops in crop rotation and in intercropping systems (Stagnari *et al*., 2017), and each system has both advantages and disadvantages.

Intercrops may function like weeds to compete with light, water and nutrients and, therefore, they may reduce growth and yield of main crops. However, intercrops are expected to provide a higher additional income to reimburse for yield loss. In baby corn production, growing legume crops as green manure and economic crops in crop rotation is not well-accepted by baby corn growers because baby corn is a cash crop that provides a high income in a short crop cycle of about 50 days and the growers do not enjoy a high income during growing of legume crops. The possible option to meet the income criterion of the growers might be to grow pulse legumes in intercropping systems because baby corn growers had an additional income from legume crops.

The questions underlying the research project are, if pulse legumes provide additional income to the growers, and which pulse legume is the most suitable for baby corn based intercropping systems. The authors also assumed that growing pulse legumes in intercropping system with baby corm might increase soil fertility. The objectives of this study were to compare growth and yield of baby corn and pulse legumes in intercropping systems, to determine nitrogen accumulation in corn and pulse legumes, to analyze nitrogen residue in the soil after incorporation of baby corn and pulse legumes into the soil and to evaluate the benefit of the baby corn based intercropping system with pulse legumes. The information obtained in this study is important for providing recommendations to baby corn growers for baby corn based intercropping systems with pulse legumes.

MATERIALS AND METHODS

Experiment design and crop management

An F_1 hybrid (Kasetsart 3) of baby corn was used in this study. The hybrid is cytoplasmic male sterile (C type) developed by Kasetsart University (Kasetsart University Research and Development Institute, 2019). Three types of pulse legumes were used in this study, including mungbeen (*Vigna radiata* (L.) Wilczek), soybean (*Glycine max*) and crawling cowpea (*Vigna unquiculata* L. Walp). Mungbean (cv Kumpaengsaen) and soybean (cv. Chiangmai 60) have determinate growth habit, while crawling cowpea (local variety) has an indeterminate growth habit.

Four treatments consisting of baby corn alone, baby corn with mungbean, baby corn with soybean and baby corn with crawling cowpea were assigned in a randomized complete block design with three replications at National Corn and Sorghum Research Center (Suwan farm), Pak Chong district in Nakhon Ratchasima province during November 2018 to January 2019. The plot size of 3×15 m with four rows of baby corn was used in this study.

The soil in the experiment is Pak Chong series (very fine, kaolinitic, isohyperthermic rhodic kandiustox) (Division of Soil Resources Survey and Research, 2020). Organic matter is medium in the upper soil and low in the lower soil. Soil pH is in the range of 6.0 to 7.0 in the upper soil and 4.5 to 5.5 in lower soil. Exchangeable cation is medium in the upper soil and low in the lower soil. Phosphorus and potassium are medium in upper soil and low in lower soil. Conventional tillage was practiced for soil preparation. The soil ridges were constructed at the distance of 75 cm. Baby corn was planted on soil ridges at the spacing of 25×75 cm at the rate of three seeds per hill, and the seedlings were thinned to obtain two seedlings per hill at two weeks after planting. Weed control was done manually at 2-3 week intervals, and drip irrigation system was available to supply water to the crop.

The legumes were planted with spacing of 25×75 cm on the alternate hills of baby corn in the same planting date. Three seeds were planted in each hill and the seedlings were thinned to obtain two plants in each hill at two weeks after planting. Therefore, the spacing of baby corn with each legume was 12.5×75 cm and the population density was double. Crop management for legumes was similar to that for baby corn. Rhizobium was not inoculated to the legumes as the experimental site had the history of legume cultivation and indigenous rhizobium was expected to exist in the soil.

Fertilizer formula 15-15-15 of NPK at the rate of 600 kg ha^{-1} was applied to the crop as a basal dose at planting. Nitrogen fertilizer in the form of urea was applied to the crop at the rate of 100 kg ha^{-1} at 25 days after planting.

Data collection

Ear fresh weight and shoot dry weight**:** Baby corn was harvested at 50 days after planting (DAP). Leguminous crops were harvested at 65 DAP. The authors were unable to extend the harvest time of leguminous crops more than 65 DAP because, in practice, and the farmers have to use the land for the succeeding crop once they harvest baby corn. All bordered plants in the plots were harvested and the plants at the ends of the plots were discarded. Only the ears of marketable size were harvested, leaving the small ears on the stems. The stems were cut at the ground surface and stems and ears were weighted in the field. The stems in each plot were sub-sampled and the sample of 10 kg in each plot was oven-dried to obtain stem dry weight. Then, shoot dry weight was calculated from dry sample and wet sample.

Yield and shoot dry weight of legumes**:** Pulse legumes were harvested at maturity for each crop approximately at two weeks after corn harvest. All mature pods of bordered plants in each plot were harvested in the field. The plants were cut at ground level and weighed in the field. The stems in each plot were sub-sampled and the sample of 10 kg in each plot was oven-dried to obtain stem dry weight.

The pods were air-dried and threshed. The seeds were weighted to obtain seed weight. The sub-samples were oven-dried and weighed to obtain stem dry weight, and shoot dry weight was calculated from dry sample and wet sample.

Nitrogen uptake**:** Nitrogen uptake for baby corn and pulse legumes were analyzed by Kjeldahl method (Chu *et al*., 2004; Bremner, 1996). The method is briefly described as follows. The shoot sample was oven-dried at 75 °C for 3 days and ground to pass through a 32 mesh sieve and was mixed thoroughly. The samples were then digested in a digestion block chamber (Dry block bath, AI-1000, Scinics corporation, Japan). Nitrogen was determined by emission spectrography using an analyzer (JASCO N-150, Jasco International Co., Ltd., Japan). The samples were duplicated three times. The nitrogen uptake by shoots of baby corn and pulse legumes for each plot was calculated as below;

Nutrient uptake = (Nitrogen content × Shoot dry weight)/100.

Income: Income was calculated from baby corn yield and legume yield using the most recent market prices (Table 01) (Office of Agricultural Economics, 2018), and the additional income was determined as the difference between baby corn alone and baby corn with pulse legumes.

Data analysis

Analysis of variance was performed for all parameters under study according to a randomized complete block design (Gomez and Gomez, 1984). Means were separated by Duncan's multiple range test at 0.05 probability level. All calculations were performed by using Statistix 8 software (Analytical Software, Tallahassee, FL, USA). Income and percentage were calculated in Microsoft Excel.

RESULTS AND DISCUSSION

Crop productivity

Intercropping of baby corn with pulse legumes did not have significant effects on husked ear yield and shoot dry weight of baby corn (Table 02). Husked ear yields ranging from 5.19 to 6.69 tons ha^{-1} were observed among the treatments. Baby corn alone was the highest (6.69 tons ha^{-1}) followed by baby corn with mungbean (6.44 tons ha^{-1}), baby corn with soybean (5.50 tons ha^{-1}) and baby corn with crawling cowpea (5.19 tons ha^{-1}), respectively. In terms of shoot dry weight, baby corn alone was still the highest (6362.81 kg ha^{-1}) followed by baby corn with soybean (6200.50 kg ha^{-1}), baby corn with crawling cowpea (6138.81 kg ha^{-1}) and baby corn with mungbean (5850.69 kg ha^{-1}), respectively.

Table 01: The recent market prices of baby corn, mungbean, soybean and crawling cowpea.

Commodity	Price (kg/USD[1/]
Baby corn	1.150
Mungbean	0.854
Soybean	0.434
Crawling cowpea	0.920

Source: Office of Agricultural Economics (2018)

[1/] *In Thai Baht with conversion rate of 30.42*

Table 02: Means for husked baby corn yield, shoot dry weight of corn (without ear), pulse legume yield (dry seeds) and shoot dry weight of pulse legume (without pod) of baby corn and pulse legumes grown in intercropping systems.

Treatment	Husked ear yield (tons ha^{-1})	Shoot dry weight of corn (kg ha^{-1})	Pulse legume yield (kg ha^{-1})	Shoot dry weight of pulse legume (kg ha^{-1})
Baby corn alone	6.69	6362.81	ND	ND
Baby corn with mungbean	6.44	5850.69	37.06b	133.31c
Baby corn with soybean	5.50	6200.50	140.75a	1365.81b
Baby corn with crawling cowpea	5.19	6138.81	148.12a	2389.19a
Mean	5.95	6138.20	108.65	1296.10

ND=not determined

Means in the same column followed by the same letter are not significantly different by DMRT at 0.05 probability level.

In this study, although intercropping of baby corn with pulse legumes did not significantly reduce baby corn growth and productivity, they did reduce growth and productivity of the corn in all treatment combinations and the most reductions were found in baby corn with crawling cowpea and mungbean, respectively. The reductions in growth and productivity of baby corn were not surprising as pulse legumes acted as weeds that competed with baby corn for water, nutrients and solar radiation (Silva *et al*., 2015). As nitrogen fixing crops and pulse legumes, the authors expected to find the benefit of the legumes from nitrogen fixation and the additional income that was high enough to reimburse the crop loss from competition.

The differences among legume species were significant (P≤0.05) for these traits. Pulse legume yields ranged from 37.06 kg ha^{-1} to 148.12 kg ha^{-1}. Baby corn with mungbean was the lowest (37.06 kg ha^{-1}), and baby corn with soybean was intermediate (140.75 kg ha^{-1}) and baby corn with crawling cowpea was the highest (148.12 kg ha^{-1}). Similar to pulse legume yield, pulse legumes were significantly different (P≤0.05) for shoot dry weight. Baby corn with mungbean was the lowest (133.31 kg ha^{-1}), baby corn with soybean was intermediate (1365.81 kg ha^{-1}) and baby corn with crawling cowpea was the highest (2389.19 kg ha^{-1}).

The legumes were selected because they are different in growth habits and the ability to compete with baby corn. In this study, crawling cowpea showed the most promising legume for intercropping with baby corn as indicated by its highest shoot dry weight and seed yield. These legumes might also be different in nitrogen fixation.

Nitrogen uptake

The treatments were not significantly different for nitrogen uptakes in baby corn shoot, which ranged from 32.19 kg ha^{-1} for baby corn with mungbean to 35.00 kg $^{-1}$ for baby corn alone (Table 03). However, significant differences (P≤0.05) among the treatments were observed for nitrogen uptake in legume shoot, total nitrogen uptake and percentage of nitrogen uptake.

Nitrogen uptake in legume shoot for baby corn alone was not determined because no legume was planted in this treatment, and nitrogen uptake for this treatment may be considered to be zero. Among the treatments with legumes, baby corn with mungbean had the lowest nitrogen uptake of 0.50 kg ha^{-1}, baby corn with soybean was intermediate (37.06 kg ha^{-1}) and baby corn with crawling cowpea was the highest (69.75 kg ha^{-1}).

Total nitrogen uptake and percentage of nitrogen uptake followed the similar pattern of nitrogen uptake in legume shoot. Baby corn alone and baby corn with mungbean were the lowest for total nitrogen uptake (35.00 and 32.69 kg ha^{-1}) and percentage of nitrogen uptake (0.55 and 0.39 %). Baby corn with soybean was intermediate (71.00 kg ha^{-1} and 2.72%), whereas baby corn with crawling cowpea was the highest (103.50 kg ha^{-1} and 2.92%).

Table 03: Means for nitrogen in corn shoot, nitrogen in legume shoot, total nitrogen and percentage of nitrogen.

Treatment	Nitrogen in corn shoot (kg ha^{-1})	Nitrogen in legume shoot (kg ha^{-1})	Total nitrogen (kg ha^{-1})	Percentage of nitrogen (%)
Baby corn alone	35.00	ND	35.00c	0.55c
Baby corn with mungbean	32.19	0.50c	32.69c	0.39c
Baby corn with soybean	34.12	37.06b	71.00b	2.72b
Baby corn with crawling cowpea	33.75	69.75a	103.50a	2.92a
Mean	33.76	35.77	60.55	1.64

ND=not determined

Means in the same column followed by the same letter are not significantly different by DMRT at 0.05 probability level.

As nitrogen uptakes were not significantly different in baby corn, the main cause of variation in nitrogen uptake among the treatments was legume species. In this study, the most promising legume in the term of providing residual nitrogen to the soil was crawling cowpea.

Nitrogen fixation and nitrogen residues returned to the soil after harvest of legumes have been extensively investigated for pulse legumes and other types of legumes such as green manure and cover crops (Stagnari *et al*., 2017). Pulse legumes are interesting as they provide cash for farmers and, at the same time, fixed nitrogen may be beneficial to the soil and succeeding crops.

According to Flynn and Idowu (2019), when the grain from a grain legume crop is harvested, little nitrogen is returned for the following crop. Most of the nitrogen fixed during the season is removed from the field as grain. The stalks, leaves, and roots of grain legumes, such as soybeans and beans, contain about the same concentration of nitrogen as found in non-legume crop residue. In fact, the residue from a corn crop contains more nitrogen than the residue from a bean crop simply because the corn crop has more residue left after the harvest of corn. To the best of our knowledge so far, the information on nitrogen fixation in crawling cowpea is not available in the literature. However, bulk information is available for cowpea (Vigna unguiculata) with similar growth habit. In crawling cowpea, it had a great nitrogen fixing potential and some fixed nitrogen returned to the soil after harvest (Senaratne *et al*., 1995). It seemed likely that symbiotic nitrogen fixation of crawling cowpea was not suppressed by nitrogen application. According to Khan and Yoshida (1995), symbiotic nitrogen fixation in peanut was not suppressed by nitrogen application even at high dose.

Peanut is another promising pulse legume for its residue (haulm) quality for soil improvement after pods are removed from the field. In a study on nitrogen fixation of pulse legumes including soybean and peanut, peanut had high net nitrogen contribution, while soybean had high net nitrogen removal, when stover was returned to the soil, because soybean had higher % nitrogen harvest index (Toomsan *et al*., 1995). Seed removal from the field had a negative nitrogen balance in the soil in all the genotypes of mungbean, but some genotypes of peanut produced a positive nitrogen balance in the soil (Senaratne and Gunasekera, 1994). The results from previous studies indicated that nitrogen fixing ability of pulse legumes depended on legume species and genotypes.

As crop duration of baby corn is short (50 days) and days to harvest of most pulse legumes are much longer, pulse legumes might be not suitable for intercropping with baby corn. However, they might be used in other cropping systems such as the strip cropping system and crop rotation.

Unfortunately, the authors unable to separate fixed nitrogen and nitrogen from the soil (both soil residue and applied nitrogen). However, biological nitrogen fixation is not so different from chemical nitrogen fixation in both methods that required high energy (Wagner, 2011). Therefore, nitrogen fertilizer inhibited nitrogen fixation even if nodules are formed (Dogra and Dudeja, 1993). In this study, nitrogen fixation of pulse legumes is expected to be low because of high application of nitrogen fertilizer to baby corn. In baby corn production, it is inevitable to apply a high dosage of nitrogen to the crop to obtain an acceptable yield except that the soil is very fertile.

Profitability

Intercropping of baby corn with pulse legumes may improve profitability of baby corn growers because the systems may exploit nitrogen fixation from legume crops. In this study, the incomes from baby corn ranges from 5937.29 USD ha^{-1} for baby corn with crawling cowpea to 7654.10 UDS ha^{-1} for baby corn alone (Table 04). The authors did not test statistical significance because the data were derived from crop yield. However, there was a trend that pulse legumes reduced income compared to baby corn alone.

Table 04: Income from baby corn, pulse legume, total income and additional income.

Treatment	Income from baby corn (USD)	Income from legume (USD)	Total income (USD)	Additional income (USD)
Baby corn alone	7654.10	ND	7654.10	ND
Baby corn with mungbean	7367.97	31.51	7399.48	-254.62
Baby corn with soybean	6294.96	60.75	6355.72	-1298.38
Baby corn with crawling cowpea	5937.29	135.62	6072.92	-1581.18
Mean	6813.58	75.96	6870.56	-1044.73

ND=not determined

Baby corn alone did not have an income from legume crop and the income was considered to be zero. The incomes from pulse legumes ranged from 31.51 USD ha^{-1} for mungbean to 135.62 USD ha^{-1} for crawling cowpea, and soybean were intermediate (60.75 USD ha^{-1}). Although baby corn alone did not have a contribution from legume, it still had the highest income of 7654.10 USD ha^{-1}, and the lowest income (6072.92 USD ha^{-1}) was obtained from baby corn with crawling cowpea, whereas baby corn with mungbean and baby corn with soybean were intermediate (7399.48 and 6355.72 USD ha^{-1}, respectively).

Additional incomes for all treatments with legumes were negative, suggesting that legume crops reduced income from baby corn and the incomes from legume crops could not reimburse for crop loss. Reduction in income was the highest in baby corn with crawling cowpea (-1581.18 USD $ha^{-1)}$ followed by baby corn with soybean (-1298.38 USD ha^{-1}), whereas baby corn with mungbean was the lowest (-254.62 USD ha^{-1}).

Although pulse legumes did not provide a sufficient additional income, vegetable legumes such as normal yard long bean, supportless yard long bean, green pea and sugar bean are interesting as these legume crops are harvested as fresh vegetables and the possibility to success might be higher than dry bean. Another possible means to increase income is to increase population density of baby corn as plant population density used for baby corn is similar to that used for field corn and specific population density is necessary for the newly-released varieties. Further investigations on intercropping of baby corn with vegetable legumes and plant population density of baby corn are still required.

CONCLUSIONS

In this study, intercropping of baby corn with pulse legumes was expected to provide an additional income to baby corn growers as pulse legumes may provide a sufficient additional income to reimburse crop loss from competition. However, the information obtained from the experiment did not support the assumption of the study. Intercropping of baby corn with pulse legumes reduced growth and yield of baby corn. The additional incomes from all pulse legumes did not exceed the values of crop losses for all treatment combinations of intercropping. Therefore, intercropping of baby corn with pulse legumes is not recommended. However, pulse legumes especially, for crawling cowpea could improve quality of crop residues that may be beneficial to soil improvement and the succeeding crop.

The experiment was limited to one season and three pulse legume species. Therefore, care must be taken to extrapolate the results to other pulse legume species and other growing conditions. Although the experiment was limited, the results pointed out that intercropping of baby corn with pulse legumes was not profitable. This information is important for research community and agricultural extension to provide information to baby corn growers.

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