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# Effect of Combined Application of Poultry Manure and Inorganic Fertiliser on Yield and Yield Components of Maize Intercropped with Soybean

**Almaz, M. G., R. A. Halim* and M. Y. Martini**

*Faculty of Agriculture, Universiti Putra Malaysia, 43400 UPM, Serdang, Malaysia*

## ABSTRACT

A field experiment was conducted to evaluate the effect of the combined application of poultry manure and inorganic fertiliser on yield and the yield component of maize (*Zea mays L*) and soybean (*Glycine max L. Merril*) intercrops. Treatments comprised combinations of three intercropping systems (sole maize, sole soybean and maize+soybean) and four nutrient management practices [control, 100% NPK, 100% poultry manure (PM) and 50 % NPK+50% PM]. The experiment was laid out in a randomised complete block design (RCBD) with three replications. The results revealed that intercropping of maize with soybean significantly reduced soybean yield and yield components, but maize yield and yield traits were not significantly affected by intercropping. Land Equivalent Ratio (LER) was >1, indicating a beneficial effect of intercropping soybean with maize. For both maize and soybean, there were no significant differences in yield between application of 100% NPK and the 50% NPK+50% PM fertiliser. A combined application of 50% NPK and 50% PM gave the highest monetary advantage in intercropping system. It can be concluded that a 50% substitution of inorganic fertiliser with poultry manure is recommended to reduce use of chemical fertilisers without sacrificing crop yield..

*Keywords*: fertiliser, intercropping maize/soybean, NPK, poultry manure, yield

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*E-mail addresses*:
almimeseret@gmail.com (Almaz, M. G.),
ridzwan@upm.edu.my (R. A. Halim),
martinimy@upm.edu.my (M. Y. Martini)
* Corresponding author

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## INTRODUCTION

Maize (*Zea mays L*) and soybean (*Glycine max* L. Merril) are important cereal and legume crops, respectively. The maize-soybean intercropping system is one of the profitable cropping systems. Nevertheless, the productivity of the system in most developing countries is low and has been ascribed to several constraints. Low soil fertility due to use of unbalanced and inadequate fertilisers and biomass removal accompanied by restricted use of organic manures are some of the major causes for declining productivity of the system (Negassa et al., 2007). Due to the high cost of chemical fertilisers, marketing problems and poor infrastructure, only a limited number of farmers in developing countries apply inorganic fertiliser and, in most cases, at lower rates than recommended (Morris et al., 2007). Long-term use of only chemical fertilisers in a continuous cropping system leads to nutrient imbalance in the soil, which adversely affects soil and crop productivity (Mahajan et al., 2008).

On the other hand, continuous use of organic fertiliser improves soil organic matter and soil productivity. However, nutrients in organic fertilisers are released much more slowly and cannot increase crop yield within a short time as compared to inorganic fertilisers (Negassa et al., 2007). Therefore, use of organic fertiliser alone does not result in remarkable increase in crop yields due to their low nutrient status. This has led to a quest for the use of integrated nutrient management as a sustainable solution and better utilisation of resources to produce crops with less expenditure. Integrated use of different fertiliser sources with an appropriate cropping system can result in improved soil fertility, crop productivity and a better environment for future generations. This study was aimed at determining the effect of combined application of poultry manure and inorganic fertiliser on yield and yield component of maize and soybean intercrops.

## MATERIALS AND METHODS

A field experiment was carried out in 2014 at the University Research Park of Universiti Putra Malaysia. The initial physicochemical properties of the experimental field soil were as follows: pH 5.6, organic carbon 1.14%, N 0.08 %, S 0.007%, P 10 ppm, K 0.167 cmol/kg and sandy loam in texture.

The experiment was conducted using 3x4 factorial combinations of intercropping systems (sole maize, sole soybean and maize+soybean) and nutrient management practices [control, 100% NPK, 50% NPK+50% poultry manure (PM) and 100% PM] and laid out in Randomised Complete Block Design (RCBD) with three replications. The plot size of 3.6 m x 3 m was used for all treatments. The plant materials used for this study were the maize variety Sweet Corn 926 and the soybean variety Willis.

The amount of PM was based on N equivalence and applied on dry weight basis two weeks before planting. The amount of PM in sole maize, sole soybean and intercropping plot were 3 t ha$^{-1}$, 0.4 t ha$^{-1}$ and 3 t ha$^{-1}$, respectively. The chemical composition of PM is presented in Table 1.

The amount of $N:P_2O_5:K_2O$ for 100% NPK treatment was 120:60:40 and 20:60:40 kg ha$^{-1}$ for maize and soybean monocrop, respectively. The intercropped plots received the recommended fertiliser rate for maize ($N:P_2O_5:K_2O$ at 120:60:40 kg ha$^{-1}$). The full dose of P and K and one third of N fertiliser were applied at planting time. The remaining two thirds of N fertiliser was applied at the 8-leaf stage of maize, while for soybean plots the entire dose of NPK was applied at planting. All other agronomic practices were kept uniform for all treatments.

Table 1
*Chemical Composition of Poultry Manure*

| Nutrient Element | Values (%) |
|---|---|
| N | 4.50 |
| P2O5 | 2.50 |
| K2O | 2.00 |
| CaO | 2.00 |
| MgO | 1.00 |
| S | 0.50 |
| Fe | 0.04 |
| Mn | 0.09 |
| Zn | 0.09 |
| Other characteristics | 0.50 |

Maize and soybean were planted manually by placing two seeds per hill on 10 April, 2014. The plants were thinned to one plant per hill two weeks after emergence to maintain the recommended intra-row population for both crops. The sole maize and soybean samples were seeded in six rows spaced 60 cm between rows in the monoculture plots. Maize and soybean were intercropped in 1:1 alternate rows with 60cm space between maize and soybean rows. The spacing between plants for maize was 25 cm and for soybean, 15 cm. Maize and soybean were harvested manually at physiological maturity and samples were taken from a sample quadrat of 2 m x 2 m for each plot.

Data recorded for maize include plant height, cob length, green cob weight, 1000 kernel weight, number of kernels per cob, green cob yield (kg/ha) and total dry biomass (kg/ha). For soybean, data taken included plant height, number of branches per plant, number of pods per plant, seeds per pod, seed yield per plant, hundred seed weight, seed yield (kg/ha) and total dry biomass (kg/ha). All the measured data were subjected to analysis of variance (ANOVA) appropriate to a factorial experiment in RCBD. Analysis of variance was computed using the SAS (Version 9.4) statistical software programme. The Least Significant Difference (LSD) was used for mean separation at 0.05% probability levels. The model for the two-way ANOVA with interaction is:

$$Y_{ijk} = \mu + \tau A_i + \tau B_j + (\tau A \tau B)_{ij} + \beta_k + \varepsilon_{ijk} \quad (1)$$

where $Y_{ijk}$ is the random variable representing the response for treatment i

j observed at block K, $\mu$ is the overall mean of all experimental units

$\tau A_i$ is the effect of factor A at level i

$\tau B_j$ is the effect of factor B at level j

$(\tau A \tau B)_{ij}$ is the interaction between factor A and B at levels i and j

$\beta_k$ is the effect of block k, and

$\varepsilon_{ijk}$ are random errors for the i, j and ij in the k block.

The advantage of intercropping was measured through land equivalent ratio (LER) based on equation 2:

$$LER = (Yij/Yii) + (Yji/Yjj) \quad (2)$$

where Yii and Yjj are yields of sole crop i and j, respectively

Yij is the intercrop yield of i, and

Yji is the intercrop yield of j.

The profitability of intercropping over monocropping was measured by Gross Monetary Value (GMV) and Monetary Advantage (MA) (Mead & Willey, 1979). GMV was calculated based on market price [Malaysian Ringgit (RM)] of a green cob of maize and seed of soybean. Therefore, GMV and MA were calculated based on equation 3 and 4, respectively (Willey, 1979):

$$GMV = (\text{yield of component crops}) \times (\text{market price}) \quad (3)$$

$$MA = (\text{value of combined intercrops yield}) \times (LER-1) / LER \quad (4)$$

The market price of a green cob of maize (RM 1.15 per cob) and seed of soybean (RM 9 per kg) was estimated based on their average price in 2015 at three main markets in the study area.

The net return (NR) was calculated from the difference of gross monetary value and variable cost (CIMMYT, 1988). Total variable cost (TVC) was the sum of the cost of fertiliser and cost of time expended to spread the fertilisers. Fertilisers were valued at an average price of poultry manure (PM) (RM 0. 977 per kg), Urea (RM 2.3 per kg), Triple Super Phosphate (TSP) (RM 3.38 per kg) and Muriate of potash (MOP) (RM 2.88 per kg). The daily wage rate was based on the wage rate in the study area (RM 70 per day).

## RESULTS AND DISCUSSION

### Maize

The results showed that nutrient management had a significant effect on plant height (Table 2). However, there was no significant effect of intercropping on plant height of maize. Among nutrient management treatments, 100% NPK and 50% NPK+ 50% PM gave the tallest maize followed by 100% PM, while the shortest plant was obtained in control plots. The plant growth was inhibited due to limited supply of nutrients in the control plots. Greater plant height was attributed to the gradual release of essential nutrients as required by the plant in a combined application of NPK and PM. These results are in agreement with those of Ayoola and Makinde (2009).

Yield traits such as cob length, cob weight, 1000 grain weight and number of kernels per cob were significantly affected by nutrient management, but not by the intercropping system (Table 2). This result is consistent with that of Aziz et al. (2012), who reported that cob length and weight of seeds were not affected by the intercropping system.

Table 2
*Effect of Intercropping System and Nutrient Management on Yield and Yield Traits of Maize*

| Treatment* | PH (cm) | CL (cm) | GCW (g) | NK/C | TGW (g) | GCY (kg/ ha) | TDB (kg/ ha) |
|---|---|---|---|---|---|---|---|
| Cropping system (C) | | | | | | | |
| Sole Maize | 162 | 31 | 321 | 530 | 377 | 21,591a | 7,634 |
| Maize +soybean | 150 | 30 | 317 | 503 | 370 | 21,394a | 7,401 |
| LSD (p<0.05) | ns | ns | ns | ns | ns | ns | ns |
| Nutrient Management (N) | | | | | | | |
| Control | 107c | 28b | 229c | 391c | 320c | 9,808c | 4,466c |
| 100% NPK | 203a | 32a | 387a | 591a | 414a | 28,340a | 9,186a |
| 100% PM | 145b | 31a | 306b | 492b | 370b | 19,557b | 6,752b |
| 50%NPK+ 50% PM | 185a | 32a | 355ab | 593a | 390ab | 28,264a | 9,666 a |
| LSD (p<0.05) | 18.2 | 3.4 | 51 | 46 | 34 | 3443 | 1248 |
| C*N | ns | ns | ns | ns | ns | ns | ns |
| CV (%) | 8.98 | 9.10 | 13.03 | 7.35 | 7.54 | 13.5 | 13.6 |

Means followed by the same letter within columns are not significantly different
* PH=plant height, CL = cob length, CW = green cob weight, NK/C = number of kernel per cob, TGW = thousand grain weight, GCY = green cob yield, TDB = total dry biomass

Longer cobs, bold and heavy grain and more number of grains per cob were observed from 100% NPK and the 50% NPK+50% PM followed by 100% PM. The highest yield components in the application of 100% NPK and 50% NPK+50% PM might be due to greater availability and uptake of nutrients throughout the growing season. The lowest value for all yield components was recorded in control plots due to inadequate supply of nutrients. These results are in line with Akintoye and Olaniyan (2012) and Rehman et al. (2008), who reported higher yield components of maize in combination of organic and inorganic fertiliser.

The green ear yield and total dry biomass of maize were significantly affected by nutrient management, but not by the intercropping system (Table 2). This shows that the presence of soybean did not adversely affect the growth of maize. The present result is supported by that of Mudita et al. (2008) and Waktola et al. (2014), who reported non-significant difference between monocropped maize and intercropped maize with soybean on yield and yield components. The highest green ear yield as well as total dry biomass of maize was obtained from 100% NPK and the 50% NPK+50% PM treatment, while the lowest were recorded from the control. The use of 100% PM gave a higher yield than the control, but it was lower than the yield of the other two fertiliser treatments. This is probably due to the fact that nutrients in the inorganic fertiliser were being rapidly released and the maize was able to utilise it for its growth and yield. This result is supported by that of Ayoola and Makinde (2009), who reported the highest yield in maize that was fertilised with inorganic fertiliser. Farhad et al. (2009) also reported that yield and yield traits of maize were significantly increased by application of different levels of poultry manure compared to the control.

### Soybean

The results revealed that plant height of soybean varied significantly in response to different intercropping systems and nutrient management (Table 3). The soybean plant grown as a monocrop was shorter than that intercropped with maize. This result might have been due to the shading effect of maize, which reduced the interception of light by the soybean. The result is supported by Ijoyah et al. (2013), who reported taller soybean plants in the intercropped sample compared to that of the monocropped soybean due to the competition for light from the greater population of plants in intercropping. Among nutrient management treatments, the tallest plant was observed in the 50% NPK+50% PM and the 100% NPK treatment. The shortest soybean was observed in the control plots, followed by the poultry manure sample. The results of increasing plant height in the integrated application of organic and inorganic fertiliser may be due to the steady release of essential nutrients as required by the soybean plant. The interaction effect of the intercropping system and nutrient management was not significant on plant height of the soybean.

Number of branches per plant was significantly influenced by the intercropping system and nutrient management (Table 3). A higher number of branches per plant was obtained in the sole soybean sample compared with the soybean intercropped with maize sample. Among nutrient management, the maximum number of branches per plant was observed in the application of 50% NPK+50% PM and 100% NPK followed by 100% PM. In contrast, the number of branches per plant was noted in the control. This is in agreement with Yagoub et al. (2015), who reported the highest number of branches per plant in the combination of organic and inorganic fertilisers.

Both intercropping and nutrient management had a significant effect on the number of pods per plant and seed yield per plant (Table 3). Intercropping maize with soybean reduced the number of pods and seed yield per plant of soybean. This might be due to the inhibition of initiation of pods by soybean plants attributed to strong competition with maize. This result is supported by Zerihun et al. (2013), who reported the reduction of seed yield and number of pods per plant of soybean in intercropping. Application of 50% NPK+100% PM and the 100% NPK treatments produced the highest number of pods per plant and seed yield per plant. The lowest number of pods per plant and seed yield per plant was found in the control treatment and the 100% PM treatment.

Table 3
*Effect of Intercropping System and Nutrient Management on Yield and Yield Components of Soybea*

| Treatment* | PH (cm) | NB/P | NP/P | NS/P | HSW (g) | SY/P (g) | SY (kg/ha) | BY (kg/ha) |
|---|---|---|---|---|---|---|---|---|
| Cropping system (C) | | | | | | | | |
| Sole soybean | 80.9b | 6.97a | 136a | 2.75a | 11.3a | 55.0a | 3,236a | 7,071a |
| Maize +soybean | 95.1a | 6.28b | 116a | 2.73a | 10.8a | 43.4b | 2,560b | 5,487b |
| LSD (p<0.05) | 7.7 | 0.58 | 14 | ns | ns | 4.80 | 208.61 | 397 |
| Nutrient Management (N) | | | | | | | | |
| Control | 66.7c | 4.11c | 83c | 2.68a | 10.7a | 30.4c | 1,618c | 3,642c |
| 100% NPK | 98.4a | 8.16a | 160a | 2.78a | 11.2a | 59.7a | 3,475a | 7,350a |
| 100% PM | 83.0b | 5.88b | 103.2b | 2.75a | 11.2a | 45.9b | 2,862b | 6,641b |
| 50 % NPK+ 50% PM | 103.9a | 8.35a | 163a | 2.77a | 11.2a | 60.9a | 3,637a | 7,483a |
| LSD (p<0.05) | 10.8 | 0.822 | 20 | ns | ns | 6.8 | 295 | 561 |
| C*N | ns | ns | ns | ns | ns | ns | ns | ns |
| CV (%) | 10.04 | 10.14 | 13.20 | 2.58 | 11.5 | 8.47 | 8.20 | 7.2 |

Means followed by the same letter within columns are not significantly different
* PH = plant height, NB/P = number of branches per plant, NP/P = number of pods per plant (NP/P), NS/P = number of seeds per pod, HSW = hundred seed weight, SY/P = seed yield per plant, SY= seed yield and TDB = total dry biomass

The highest number of pods and seed yield per plant in the combined application of organic and inorganic fertilisers was probably due to a balanced supply of nutrients to the crops throughout the crop growth period as PM undergoes decomposition, during which a series of nutrient transformation phases take place that makes the nutrients available to the crops. This result is in agreement with Khaim et al. (2013), who reported that the highest seed yield per plant and number of pods per plant of soybean was in the application of 100% NPK and NPK+PM.

The main and interaction effect of intercropping systems and nutrient management was not significant on the number of seeds per pod and 100 seed weight (Table 3). This result is supported by Ali et al. (2015), who reported that the cropping system had no significant effect on the weight of the 100 seeds and the number of seeds per pod of soybean.

Seed yield and total biomass of soybean were significantly affected by the intercropping system and nutrient management (Table 3). The seed yield of soybean was reduced by 26% and total biomass of soybean was reduced by 28% when intercropped with maize. This might have been due to competition for light between maize and soybean in the mixtures. The result is consistent with that of Dolijanović et al. (2013), who reported that the yields of soybean in maize-soybean intercrops were significantly lower than those obtained in the sole crop. Among nutrient management treatments, the highest seed yield and total biomass was obtained from 50% NPK+50% PM and the 100% NPK treatments. The increase in seed yield was due to the increase in the number of branches and pods per plant. Application of 100% PM also gave higher yield than the control treatment. These results are in agreement with Khaim et al. (2013) and Yamika and Ikawati (2012), who reported higher yield due to the application of PM compared to control.

## Intercropping Advantage

Land equivalent ratio (LER) reflected the advantage of intercropping over the sole cropping system. The partial LER of maize was greater than that of soybean in all nutrient management treatments (Table 4). Higher partial LER of maize indicated the dominance of maize over soybean in intercropping. The LER of intercropping was more than one in all nutrient management samples, indicating the yield advantage of maize-soybean intercropping over monocropping (Ofori & Stern, 1987). The better utilisation of growth resources by component crops in intercropping systems led to the higher LER. This result is supported by Shaker-Koohi and et al. (2014), who explained that the greater LER could be attributed to the morphological differences of the two crops and the optimal utilisation of resources.

Table 4
*Intercropping Productivity Index as Influenced by Nutrient Management*

| *Treatment | PLER | | TLER | GMV RM/ha | MA RM/ha | TVC RM/ha | NR RM/ha |
|---|---|---|---|---|---|---|---|
| | Maize | Soybean | | | | | |
| Control | 0.86b | 0.69b | 1.55c | 30,693c | 10,381c | 0c | 30,693d |
| 100% NPK | 0.97ab | 0.83a | 1.75b | 68,061a | 28,512ab | 6,920a | 61,141b |
| 100% PM | 0.90a | 0.76ab | 1.70b | 51,748b | 25,089b | 7,157a | 44,591c |
| 50% NPK +50% PM | 0.97a | 0.77a | 1.82a | 72,405a | 30,691a | 6,753b | 65,652a |
| LSD (P< 0.05) | 0.10 | 0.14 | 0.15 | 6503 | 5022 | 1281 | 4411 |

Means followed by the same letter within columns are not significantly different
*PLER = partial land equivalent ratio, TLER = total land equivalent ratio, GMV = gross monetary value MA= monetary advantage, TVC= total variable cost, NR = net return

Among nutrient management treatments, a higher total LER was observed in the 50% NPK+50% PM treatment followed by the 100% NPK and 100% PM treatment. In contrast, the lowest LER was recorded in the control; this confirms that the productivity of intercropping systems was reduced by low soil fertility (Table 3). This result was in agreement with that of Zerihun et al. (2013), who found that the highest LER of the maize-soybean intercropping system was from the integrated use of 55/23 N/$P_2O_5$ kg ha$^{-1}$ and 8 t ha$^{-1}$ FYM.

Gross monetary value (GMV) of maize/soybean intercropping was significantly affected by nutrient management (Table 4).

The highest GMV was observed in the 50% NPK+50% PM and 100% NPK treatment followed by the 100% PM treatment, while the lowest GMV value was recorded in the control. This might have been due to higher green cob yield and seed yield values from the 50% NPK+50% PM plots, which contributed more to gross monetary value than the other treatments.

Monetary Advantage (MA) in maize/soybean intercropping system was positive, indicating productivity and profitability of the system compared to monocropping. The MA was mainly dependent on the market price of the produce and the harvested economic yield. Similarly, the MA was significantly different among nutrient managements (Table 4). The highest MA was obtained from the combined application of 50% NPK+50% PM, while the lowest was from the control in the intercropping system. The result was in agreement with that of Muyayabantu et al. (2013), who reported higher yield and monetary advantage index (MAI) for maize/soybean intercropping under a combined application of organic and inorganic fertiliser.

The highest net return was observed in the combined application of 50% NPK+50% PM followed by the application of 100% NPK. The application of 100% PM gave a higher net return compared to that of the control treatments. The increased yield from the combined application of 50% NPK+50% PM contributed to increasing net benefits and net return. The combined application of organic and inorganic fertiliser increased the synchrony between the nutrients released and plant uptake and hence, enhanced crop yields. This suggests that integration of organic and inorganic fertilisers is a more economically profitable approach among smallholder farmers in tropical developing countries. This result is in agreement with Mutegi et al. (2012) and Moghadamla and Mirshekari (2014), who found the highest gross and net benefit in the combined application of organic and inorganic fertiliser compared to that of the sole application of either fertiliser.

## CONCLUSION

The results of this study showed that intercropping reduced soybean yield by 21% but had no significant effect on maize yield. Maize-soybean intercropping was shown to have greater productivity per unit area and profitability than monocropping of either maize or soybean alone based on Land Equivalent Ratio (LER) and Monetary Advantage (MA). Among nutrient management treatments, 50% NPK+50% PM and 100% NPK were found to be the best nutrient management options for a high green cob yield of maize and seed yield of soybean. Therefore, 50% substitution of inorganic fertiliser with poultry manure is recommended for reduction in use of chemical fertilisers without sacrificing crop yield for both monocropping and intercropping of maize and soybean.

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