# Productivity of Maize/Soybean Intercrop System with NPK Fertilizer Levels and their Seed Storage in Purdue Improved Crop Storage (PICS) Bags and Diatomaceous Earth (D.E)

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***ABSTRACT***

*Food insecurity is caused mainly by inadequate soil fertility and high prevalence of storage pests. Maize and soybean are splendid food not only to man but also to other living beings. The present study was conducted to assess the productivity of maize/soybean intercrop system with inorganic fertilizer and their seed storage. The field and storage experiments were conducted at Federal University of Technology, Owerri. The field experiment was a 3×6 factorial in a randomized complete block design consisting of cropping system at three (3) levels (sole maize, sole soybean and intercrop) levels and NPK fertilizer at six (6) levels (0kg/ha, 200kg/ha, 300kg/ha, 400kg/ha, 500kg/ha and 600kg/ha) replicated thrice. The seed from the harvest of each were treatments were dusted with different levels of diatomaceous earth (D.E) (0.0g, 0.5g, 1.0g and 1.5g) and put in purdue improved crop storage (PICS) bags. Data collected were yield parameters, number of number of live Sitophilus zeamais at one month storage and number of dead S. zeamais after five month of storage. Data were subjected to statistical analysis using Gentstat and means were separated using least significant difference at 5% probability level. The productivity from the mean yield data of both crop were assessed by the land equivalent ratio. The results revealed that maize/soybean intercrop system is productive. Also the results of the seed storage experiment revealed that PICS bags alone cannot provide proper control of insect pest and therefore recommended combination of PICS bag and diatomaceous earth at 1.5g/1kg of maize for proper storage.*

***Keywords:*** *Maize/Soybean, Intercrop System, Diatomaceous earth, Bags*

## INTRODUCTION

Maize (*Zea mays*) also called corn belongs to the family poaceae plays a vital role in the food and nutrition of over one billion people in Latin America and Africa (Gupta *et al*., 2009). According to International Institute for Tropical Agriculture (2009), maize constitutes about 50% of the food consumed in Sub-Saharan Africa. Therefore shortage or absence of maize may result in serious starvation and famine. Maize is grown both at commercial and subsistence level, it important as a major food, fodder and industrial crop can hardly match other cereal crops such as millet and sorghum (Manyong *et al*., 1996; Ibeawuchi *et al*., 2007). Soybean is an important source of protein, carbohydrate, minerals, vitamins, imparts to getting better soil fertility and reduce striga infestation on farmer's field. Continues cultivation of crops has fostered the consumption of the little organic matter content and fertility status of the soil (Wu *et al*., 2003). According to Abdurrahman *et al*., (2016), endeavor aimed at obtaining high yield of crops would require augmentation of the nutrient status of the soil for higher productivity and maintaining soil fertility. This can be achieved using inorganic fertilizer such as NPK.

Researches in maize and soybean over the years have focused on the provision of improve varieties, fertilizers, modification of cropping systems and rotational cropping. These ideas considerably boosted production (Tinsley, 2009). Nevertheless, their availability in good quality for consumption is threatened by poor production practice and storage techniques. As opined by Kader (2008), for over thirty years, resources were allocated to increase agricultural production significantly but 95% of the researches targeted increasing production with only 5% focused on reduction of losses after harvest. Therefore the present studies focused both on increasing production and reduce losses in storage.

In spite of the numerous advantages of synthetic insecticides in storing grains the implication is that synthetic insecticides are expensive, they may not be available regularly and they may be illicitly blended with other undesirable compounds and their repeated application increase the chance of human environmental toxicity. Therefore there is a growing need for non chemical control methods.

The purdue improve crop storage (PICS) bag and diatomaceous has an effective alternative to chemical pesticides used in storage. The bags consist of two liners and an outer woven that provide a low oxygen environment and reduces insect development (Korunic *et al*., 1996; Murdock *et al*., 2012). Diatomaceous earth is perceive to be a sound option in storage because it has no toxicity to mammal, does not affect the end use quality and does not breakdown rapidly (Desmachelier and Dunes 1987, Korunic *et al*., 1996).

It is on the basis of the environment problems and food security that the study was designed to assess the productivity of maize/soybean intercrop system with fertilizer and their storage using PICS bag and D.E powder in Owerri, Imo state Nigeria. Whereas other specific objectives include: (1) to determine the productivity of sole maize, soybean and their intercrop using land equivalent ratio (2) to determine the effectiveness of PICS bag and D.E powder against storage pests of maize and soybean (3) to determine the optimum level of diatomaceous earth that would provide effective control of storage insects of maize and soybean.

## MATERIALS AND METHODS

### Field Evaluation

The experiment was conducted during 2018 rainy season at the Teaching and Research Farm of Federal University of Technology, Owerri, Imo State, Nigeria. The site lies between latitude $5^o27$N and longitude $7^o02$E and 55.7m above sea level located in the heart of the rainforest region of South Eastern Nigeria. It has the following climatic characteristics 1,953mm annual rainfall, mean annual temperature and relative humidity of $28^oC$ and 88%, respectively (Adeyemi, 2011). The land was repeatedly used for different crop research and was covered by small shrubs and grasses.

The trial was laid out as 3×6 factorial experiment: cropping system at three levels (sole maize, sole soybean and maize/soybean intercropping) and NPK 15:15:15 fertilizer at 6 levels (0kg/ha, 200kg/ha, 300kg/ha, 400kg/ha, 500kg/ha and 600kg/ha) fitted into a Randomized Complete Block Design (RCBD) with 3 replications. Each block contained 18 treatments which gave a total of 54 experimental units measured 3×3 = 9m$^2$.

Soybean (TGX 1835-10E) and Maize (DMR-LSRY) seeds were sown the same day. Manual weeding was carried out at 4, 7 and 10 weeks after sowing (WAS). Fertilizer application was done 3 weeks after sowing (WAS) by band placement on sole crop maize, sole crop soybean and maize-soybean intercrop at alternate rows. Maize was harvested when the cobs were dry. Further sun-drying was done before shelling, soybean was harvested later, when the leaves had turned yellow and pods sufficiently dried.

**Storage Experiment**

The materials used for the seed storage included: eight (8) purdue improved crop storage bags obtained from Bauchi State Agricultural development Program (BSADP) and diatomaceous earth powder sourced from Nigerian Stored Product Research Institute (NSPRI) Porthacourt. 200g of maize and soybean from each treatment were visually check for insect infestation and found not to be infested by insects were put in ziplock bags followed by dusting the seeds with the different D.E levels (0g/kg (control) , 0.5g/kg, 1.0g/kg and 1.5g/kg) replicated thrice. The ziplock bags containing the seeds were transferred to the PICS bags base on the treatment (PICS bag 1+0.0g/kg, PICS bag 2+0.5g/kg, PICS bag 3+1.0g/kg and PICS bag 4+1.5g/kg), the PICS bags were airtight and placed on a wooden panel that was raised above the ground level at the Department of Crop Science and Technology for five months.

**Data Collection and Analysis**

Data collected for the field experiment include cob length, cob weight, 100 seed weight per plant and grain yield of maize while that of soybean include number of pod per plant, number of seed per pods, fresh and dried pods weight, 100 seed weight and grain yield. Data collected for the storage include: number of live maize weevil (*Sitophilus zeamais*) at 1 month check, number and number of dead *S. zeamais* after 4 month of storage

The data collected were subjected to analysis of variance using Genstat software and means were separated using LSD at 5% probability level. The productivity from the mean yield data of both crop were assessed by the land equivalent ratio (LER) (Willey, 1990).

$$\text{LER} = \frac{Intercropyieldofcrop A}{Solecropyieldofcrop A} + \frac{Intercropyieldofcrop B}{Solecropyieldofcrop B}$$

Where LER is equal to 1.0, it means that there is no advantage to intercropping over sole cropping. LER above 1.0 shows an advantage while number below 1.0 shows a disadvantage in intercropping.

**Results**

**i. Field Evaluation**

Figure 1: maize and soybean in the field

**Table 1: Effect of Cropping Systems and Fertilizer Levels on the Yield and Yield Parameters of Maize**

| | Fresh cob wt (g) | Dried cob wt (g) | Fresh cob dia. | Dried cob dia. | 100 Seed wt (g) | Grain yield (kg/ha$^{-1}$) |
|---|---|---|---|---|---|---|
| **Cropping Systems** | | | | | | |
| Sole Maize | 147.09 | 97.35 | 6.61 | 3.75 | 22.26 | 859.50 |
| Intercropped Maize | 135.48 | 87.98 | 6.38 | 3.63 | 19.88 | 593.10 |
| LSD (0.05) | NS | NS | 0.15 | NS | 1.76 | 16.92 |
| **Fertilizer levels (kg/ha$^{-1}$)** | | | | | | |
| 0 | 111.54 | 75.69 | 5.83 | 2.65 | 15.10 | 579.90 |
| 200 | 159.81 | 103.48 | 6.15 | 3.95 | 21.22 | 755.75 |
| 300 | 170.64 | 115.32 | 6.75 | 4.00 | 21.96 | 829.25 |
| 400 | 136.53 | 99.05 | 6.60 | 4.01 | 23.68 | 801.55 |
| 500 | 134.84 | 80.26 | 6.58 | 3.81 | 23.79 | 727.10 |
| 600 | 134.36 | 85.43 | 6.52 | 3.72 | 19.87 | 664.30 |
| LSD (0.05) | 27.24 | NS | 0.26 | 0.23 | 3.06 | 29.31 |

Dia.= cob diameter (cm), Wt = weight

**Table 2: Effect of Cropping Systems and Fertilizer Levels on Yield and Yield Parameters of Soybean**

| | No. of pods/plant | No. of seed/pod | Fresh pod wt (g) | Dried pod wt (g) | 100 seed wt (g) | grain yield (kg/ha$^{-1}$) |
|---|---|---|---|---|---|---|
| **Cropping Systems** | | | | | | |
| Sole Soybean | 51.22 | 2.11 | 48.67 | 26.27 | 12.80 | 436.36 |
| Intercropped Soybean | 38.17 | 2.13 | 47.03 | 28.42 | 11.54 | 285.41 |
| LSD (0.05) | 6.35 | 6.35 | NS | 3.95 | 0.84 | 7.77 |
| **Fertilizer Levels (kg/ha$^{-1}$)** | | | | | | |
| 0 | 34.95 | 2.07 | 38.86 | 24.89 | 10.99 | 297.30 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 200 | 49.99 | 2.14 | 43.74 | 30.71 | 13.37 | 358.01 |
| 300 | 52.12 | 2.12 | 54.47 | 28.35 | 12.61 | 410.26 |
| 400 | 41.99 | 2.12 | 55.83 | 28.93 | 12.64 | 386.10 |
| 500 | 38.48 | 2.19 | 46.63 | 25.54 | 11.97 | 374.12 |
| 600 | 40.64 | 2.11 | 47.59 | 25.66 | 11.45 | 339.53 |
| LSD (0.05) | 11.00 | NS | 10.77 | 6.85 | 1.46 | 13.46 |

NS = Not Significant at 5% probability

**Table 3: Land Equivalent Ratio (LER)**

| | [1]Partial LER | | [2]Total LER |
|---|---|---|---|
| Cropping System × NPK levels | Maize | Soybean | |
| 0 × Maize/soybean | 0.60 | 0.66 | 1.26 |
| 200 × Maize/soybean | 0.68 | 0.59 | 1.27 |
| 300 × Maize/soybean | 0.71 | 0.65 | 1.36 |
| 400 × Maize/soybean | 0.79 | 0.63 | 1.42 |
| 500 × Maize/soybean | 0.70 | 0.70 | 1.40 |
| 600 × Maize/soybean | 0.63 | 0.69 | 1.32 |

[1]Partial LER = for maize and soybean were obtained by dividing each intercrop yield by its corresponding sole crop yield.

[2]Total LER = sum of the partial LERs of two component crops in the intercropping system.

**ii. Storage Experiment**

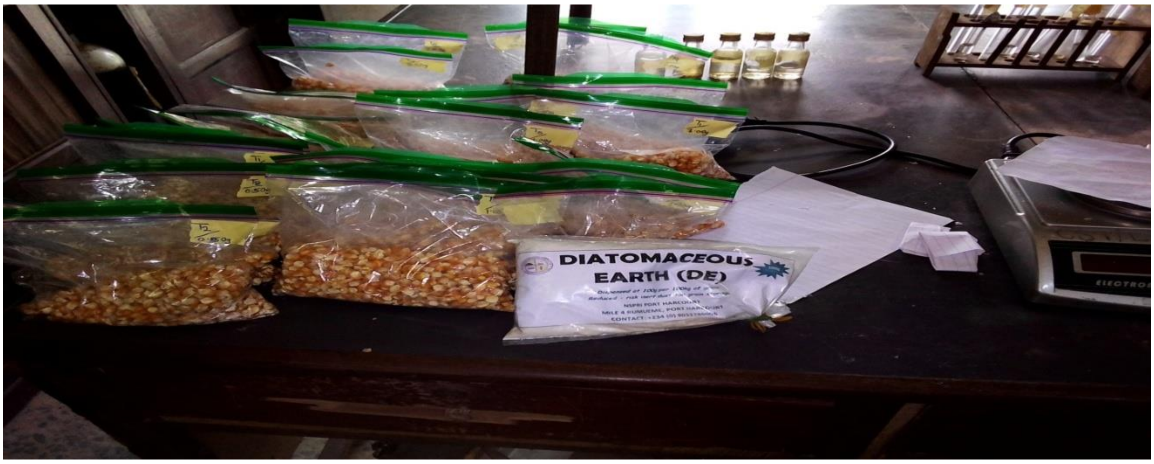


Figure 2: Weighing and dusting of the maize seeds with the different D.E levels

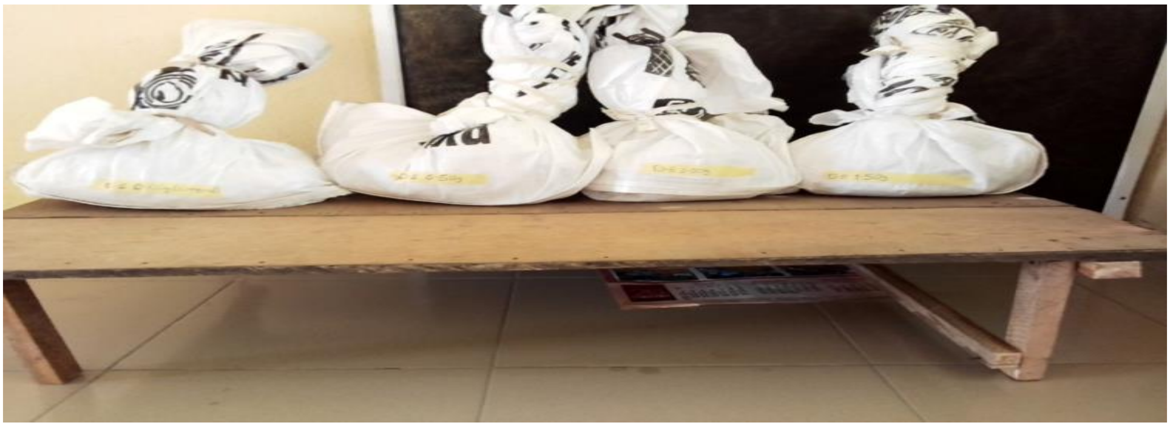

Figure 3: Five (5) month storage

**Table 4: Efficacy of Diatomaceous earth and PICS bag on number of live maize weevil (*Sitophilus zeamais*) counted at one month of storage**

| | PICS bag+0.00g | PICS bag+0.50g | PICS bag+1.00g | PICS bag+1.50 |
|---|---|---|---|---|
| **Cropping Systems** | | | | |
| Sole maize | 2.00 | ___ | ___ | ___ |
| Intercrop maize | 2.50 | ___ | ___ | ___ |
| LSD (0.05) | 0.10 | | | |
| **Fertilizer Levels (kg/ha$^{-1}$)** | | | | |
| 0 | 3.00 | ___ | ___ | ___ |
| 00 | 1.50 | ___ | ___ | ___ |
| 300 | 3.00 | ___ | ___ | ___ |
| 400 | 2.00 | ___ | ___ | ___ |
| 500 | 2.00 | ___ | ___ | ___ |
| 600 | 2.00 | ___ | ___ | ___ |
| LSD (0.05) | 0.03 | | | |

( __ ) = absence of live insect

**Table 5: Efficacy of Diatomaceous earth and PICS bag on number of dead insects counted after Five (5) month of storage**

| | PICS bag+0.00g | PICS bag+0.50g | PICS bag+1.00g | PICSbag+1.5g |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| **Cropping Systems** | | | | |
| Sole maize | 65.70 | 16.80 | 6.00 | 0.90 |
| Intercrop maize | 112.90 | 12.70 | 9.30 | 1.00 |
| LSD (0.05) | 2.11 | 1.12 | 0.01 | NS |
| **Fertilizer Levels (kg/ha$^{-1}$)** | | | | |
| 0 | 123.70 | 17.50 | 10.00 | 1.80 |
| 200 | 50.00 | 11.65 | 7.50 | 0.70 |
| 300 | 117.70 | 20.85 | 9.00 | 1.50 |
| 400 | 86.00 | 18.83 | 3.00 | 0.35 |
| 500 | 54.35 | 24.50 | 11.00 | 1.00 |
| 600 | 104.00 | 15.34 | 7.00 | 0.50 |
| LSD (0.05) | 1.22 | 1.94 | 0.03 | NS |

NS = Not Significant at 5% probability

## Discussion

### Effect of Cropping Systems and Fertilizer levels on yield and yield parameters of maize

Maize yield and yield parameters, fresh cob weight, dried cob weight and dried cob diameter were not affected by cropping systems while fresh cob diameter, 100 seeds weight and grain yield were significantly ($p<0.05$) affected by cropping system. This result is in close conformity with the findings of Ali *et al*, (2015) who reported that cob diameter were not affected by intercropping. Yield parameters of maize do not increase with increase levels of NPK fertilizer application. This may be attributed to the soil status or climatic factors like temperature, relative humidity and rainfall that interfered with the crop during their growing periods. Higher yield components of maize were recorded under sole cropping system compared to intercropping pointing out that crops in sole plots suffered less from competition. The consequences of this finding from the present study is that the nutrient requirements of maize and soybean in the intercropping system were higher than the nutrients need of either crop when grown as sole crop (Baker (1975), Mbah *et al.*, (2007) Ali *et al.*, (2015) reported that the nutrient demand of the components crops were always higher than for sole crops. The cob weight, cob diameter, 100 seeds weight and grain yield do not increase with increment in levels of NPK fertilizer application, higher yield components of maize was recorded at 300kgNPK/ha$^{-1}$ application. This result agree with the findings of Mbah *et al.*, (2007) and Ali *et al.*, (2015) who reported that application of 300kg/ha recorded the highest yield. They also reported that the nutrient needs of the intercropping components crops were always higher than for each crop when grown as sole. The implication of this finding from the study was that increase levels of NPK fertilizer up to 600kgNPK/ha$^{-1}$ did not increase the yield parameters of maize. Control plots recorded the lowest values for all yield parameters.

### Effect of Cropping Systems and Fertilizer levels on yield and yield parameters of soybean

Cropping system significantly ($p<0.05$) affected number of pods per plant, number of seeds per pods, dried pod weight, 100 seeds weight and grain yield of soybean but had no effect on fresh pod weight (Table 2). These yield responses parameters showed higher values in sole soybean compared to intercrop soybean. The result agreed with the findings of Enyi (1973) and Fisher (1977) in corn-cowpea mixtures as well as Olasantan and Lucas (1999) in maize-melon mixtures and Lesoing and Francis (1999) in maize-soybean mixtures and sorghum-soybean intercrop, Mbah *et al.*, (2015) in maize-soybean intercrop and Ali *et al.*, (2015) in maize-soybean that the sole crop components yielded higher than the corresponding crops in intercropping situation. The result showed that the levels of fertilizer applied in the cropping system significantly ($p<0.05$) affected number of pods per plant, number of seeds per pods, fresh pod weight, dried pods weight, 100 seeds weight and grain yield. These yield and yield parameters did not increase with increasing levels of NPK fertilizer application from zero to 600kgNPK/ha$^{-1}$ used in the study.

Various response of soybean to NPK fertilizer application had been reported by some researchers (Bhango and Albritton, 1972, Madimba and Mondibaye, 1996) that is not in conformity to the findings of the present study. This variation may be attributed to different type of soil, climate or fertilizer. In addition, Kang (1975) in his study reported a significant straight increase in yield of soybean to nitrogen (N) applied at 0. 30, 60 and 120kg/ha but suggest that with N at 30 kg/ha$^{-1}$ with inoculation gave significantly higher yields of soybean. Okpara *et al.*, (2002) in their study with nitrogen fertilizer within the range (0 – 80kg/ha$^{-1}$) in the humid rainforest zone report that soybean response highly as a result of the fertilizer application and conclusively noted that nitrogen alone was very effective in increasing soybean yield and yield parameters with application of up to 100kgN/ha$^{-1}$. Related work by Chizey (2001) conducted in the guinea savanna of Nigeria showed increase nitrogen fertilizer application from 0 to 80kgN/ha$^{-1}$. The results of the present study showed that soybean benefited more from the (300kgNPK/ha$^{-1}$) in both cropping systems. This study reported a similar result by Mbah *et al.*, (2007) where they investigated and showed that soybean benefited more from (300kgNPK/ha$^{-1}$).

The zero NPK (control) treatment gave the least yield and yield components assessed. The soil analysis before the conduct of the experiment showed very low nutrient levels and neutral pH level, therefore it was not surprising that yields would be low with this poor soil status. In the intercropping and sole cropping system, soybean yields were generally low due to the shading effect by the faster and taller growing maize component and because of the heavier rainfall which might have resulted to leaching of nutrients as well as competition for the available nutrients and space between the component crops.

The result agree and supported the findings of Mann and Jaworski (1970) and Mbah *et al.*, (2007) which showed that shading of soybean plants resulted to cutting of about half the pods and always lead to lower yield. Moreover, the reduction in seed yield could be ascribed to the presence of higher number of poorly developed, empty, immature and poorly filled pods.The lowest number of pods per plant, number of seed per pods, dried pod weight, 100 seeds weight and grain yield were obtained in zero level of NPK fertilizer application.

**Assessment of the Productivity of the Mixture**

The land equivalent ratio was used to assess the productivity of the component crops in intercropping system (Table 3). The study showed that maize-soybean intercropping resulted in yield advantage, the total land equivalent ratio (LER) was above 1.0 i.e (1.26, 1.27, 1.36, 1.42, 1.40, and 1.32) which showed a yield advantage due to intercropping to sole cropping of both maize and soybean. The highest LER of 1.42 was obtained in soybean and maize intercrop that received 400kgNPK/$ha^{-1}$ in the study.

**Efficacy of Diatomaceous Earth (D.E) and Purdue Improved Crop Storage (PICS) bags on the Storage Seeds**

The results showed that PICS bag storage did not completely eliminate insect but suppressed their development at one month of storage but does so after five month of storage (Table 4). However, it has resulted to about 98% reduction of storage losses and can be use for longer storage time ( 53, 56). According to Tefera *et al*., (2011) and World Bank, (2011), hermatic storage has been observed to be very effective in reducing storage losses. Another suggestion by Bakoye *et al*., (2017) revealed that low-cost PICS bag and other hermatic technologies were among the numerous technologies that are cost-effective in controlling storage insects.

These results agree with the Bakoye *et al's* finding but observed that PICS bag effectiveness against storage insect increases with increase in storage time because the absence of oxygen during storage stopped killed and stopped their development. Baoua *et al*., (2014), observed 95-100% insect mortality after $6\frac{1}{2}$ months of storage and seed viability is maintained.

The three D.E levels (0.5, 1.0 and 1.5g/kg) caused significant mortality to *S. zeamais* (Table 5), live *S. zeamais* were found in the control (0.0g/kg) and absent in the D.E applied treatments at one month of storage. The number of death insect counted in maize seeds decreased with increasing level of D.E, the insecticidal efficacy under dried condition may be due to the desiccative properties of the powder. Diatomaceous earth showed insecticidal properties on *S. zemais* this is because the D.E could contain some chemical compounds that reduced progeny production and act almost on progeny inhibition by same mechanism. The dust inhibits insect behavior, affecting movement and reproduction by blocking air space between the seeds. This result agree with the finding of Mordock *et al*., (2012) and Khakame *et al*., (2012) who reported that a D.E is very effective against *S. zeamais* progeny. Parsaeyan *et al*., (2012) found that D.E reduced the fecundity, adult longevity and egg hatching rate of storage insect. Therefore the present study revealed that the three D.E levels suppressed *S. zemais* population increase and reduced infestation.

## Conclusion

The results of the field study showed that maize and soybean could be intercrop base on the land equivalent ratio values. Fertilizer significantly increases the yield of component crops than when no fertilizer was applied. The results of the seed storage experiment showed that PICS bags alone cannot provide proper control of storage pest of maize at one month storage time but can do so when the longevity of storage is increase. PICS bags and D.E storage is found to be effective, this research finding recommended the use of PICS bag and 1.5g/kg of D.E for both short time and long time storage of maize seeds.

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**Figure 1. Field and storage experiments**