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Effect of incorporation of crop residue and inorganic fertilizer on yield and grain quality of maize

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ABSTRACT

A field experiment was conducted during 2014 at Universiti Putra Malaysia, Serdang, Malaysia, to evaluate the effect of incorporation of crop residues with supplemental inorganic fertilizers on yield and quality of maize crop. Treatments included an unfertilized control, incorporation of maize residue, soybean residue and a mixture of maize and soybean residue with and without phosphorus and potassium fertilizer and the use of a complete inorganic nitrogen, phosphorus and potassium fertilizer. Results showed that soybean and maize + soybean residue applied without inorganic fertilizers or with inorganic fertilizer (phosphorus and potassium) increased maize yield and enhanced grain quality of maize. However, incorporation of maize residue without supplemental inorganic fertilizer was ineffective in increasing grain cob yield (11,237 kg/ha) and grain quality (11.1% protein content, 10.9^{o} brix sugar content and 4.77% oil content) of the maize crop above that of control (10,323 kg/ha green cob yield, 8.30 % protein content, 9.00^{o} brix sugar content and 4.77% oil content). The application of soybean residue with supplemental phosphorus and potassium fertilizer gave maize yield (37,290 kg/ha) similar to that of the complete inorganic fertilizer treatment (36,500 kg/ha). Therefore, inorganic nitrogen fertilizer can be replaced with soybean residues without any reduction in maize yield and grain quality.

Key words: Crop residue, Inorganic fertilizer, Soil chemical properties, Yield.

INTRODUCTION

Maize (Zea mays L) or corn is one of the important cereal crops in the world next to wheat and rice. Maize serves as a staple food for over 900 million people in the developing countries, and it is the most dependable crop to bring about food self-reliance and independence (Zerihun *et al.,* 2013). However, the yield of maize in Sub-Saharan African countries and several Asian countries are extremely low, averaging approximately 1.5 t/ha and 3 t/ha, respectively (CIMMYT, 2013). In Malaysia, maize is a minor crop even though the demand for maize increases over the years. Maize is imported yearly to satisfy the country's needs. Low soil fertility due to continuous cropping with low or no external inputs and removal of crop residues, is one of the major causes for low production (Negassa *et al.*, 2007). Application of inorganic fertilizers is considered the most efficient way to reverse soil nutrient depletion and improve crop production (Bationo *et al.,* 2007). Due to the high cost of inorganic fertilizer, only a limited number of farmers in developing countries apply inorganic fertilizer and in most cases at lower rates than recommended (Morris *et al.* 2007).

Organic inputs (crop residues) are a valuable and inexpensive source of plant nutrients to maintain soil organic matter and reclaim degraded soils (Tejada *et al.,* 2008). Incorporation of crop residues in agricultural soils is primarily a means to maintain soil organic matter which results in enhanced biological activity, physical properties and nutrient availability (Antil and Narwal, 2007). The most immediate effect of residue application is on the availability of nitrogen to the succeeding crop as a result of mineralization (Hadas *et al.,* 2004). Crop residues, mainly leguminous residues, have a great nitrogen benefit and reduce the need for mineral N fertilizer application by smallholder farmers and increase their gross benefit in maize production (Svubure *et al.,* 2010). Several studies have shown that the N fertilizer requirements for optimum economic yields are less for maize succeeding soybean than for maize succeeding maize (Gentry *et al.,* 2001). However, application of crop residue alone to sustain crop productivity is inadequate due to their relatively low nutrient content particularly, P and K and slow release of nutrients (Negassa *et al.,* 2007). To achieve the sustainability of soil and crop productivity, combined use of organic and inorganic fertilizer together are very important. Integrated use of organic and inorganic fertilizers can sustain soil fertility and soil organic matter required for sustainable high yields. Therefore, the present investigation was undertaken to evaluate the effect of incorporation of crop residues with supplemental inorganic fertilizers on yield of maize crop and soil chemical properties.

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MATERIALS AND METHODS

An experiment was conducted in 2014 at Field 2, Universiti Putra Malaysia (UPM) Serdang, Selangor, Malaysia. The site is located at a latitude of 3° 02' N, a longitude of 101° 42' E and an altitude of 31 m above sea level. Total annual rainfall in the year 2014 was approximately 2689 mm with a monthly average of 224 mm. The minimum and maximum average temperatures were 25.06 °C and 32.66 °C, respectively. The initial physico-chemical properties of the experimental field soil are presented in Table 1.

The experiment was designed with eight treatments. The treatments were laid out in a randomized complete block design with three replications.

Treatments were as follows:
T1= control (no fertilizer and no crop residue)
T2= NPK fertilizers (120:60:40 kg ha^{-1})
T3= maize residue (10 t/ha)
T4= maize residue + phosphorus and potassium (PK) fertilizers (10 t/ha + 60:40 kg ha^{-1})
T5= soybean residue (7 t/ha)
T6= soybean residue + PK fertilizers (7 t/ha + 60:40 kg ha^{-1})
T7= maize + soybean residue (12 t/ha)
T8= maize + soybean residue + PK fertilizers (12 t/ha + 60:40 kg ha^{-1})

A plot size of 6.0 m x 3.6 m (21.6 m^2) was used for all treatments. Maize of variety Sweet Corn 926 was used as a test crop and planting was done on Sept 10, 2014. The crop residues were collected from the previous season from 3 cropping systems (sole maize, sole soybean, and maize + soybean intercropping) after cobs of maize and pods of soybean were harvested at 75 and 120 days after planting, respectively . The application rates were 10 t/ha of maize residue, 7 t/ha of soybean residue and 12 t/ha of maize + soybean residue, depending on the biomass produced in the respective fields. The residues were chopped (10-15 cm) and manually incorporated in the top 0-30 cm using hoes one month prior to planting. The nutrient composition of the residues was measured in the laboratory prior to the application (Table 2). The rate of N: P_2O_5:K_2O for the 100% NPK treatment was 120:60:40 kg ha^{-1} for maize crop. This application rate of NPK was based on the result of the initial soil analysis and the nutrient requirement for the crop. The full dose of P and K and one-third of N fertilizer were applied at the sowing time. The remaining two-third of N fertilizer was added at 8-leaf stage of maize as a top dressing. Other agronomic practices were kept uniform for all treatments.

Table 1: Initial physical and chemical properties of experimental soil (n=3)

Soil Properties	Value
pH	5.6 ± 0.19
Total N (%)	0.11 ± 0.02
Available P (mg/kg)	18.0 ± 1.95
Exchangeable K (cmolc/kg)	0.35 ± 0.14
S (%)	0.007 ± 0.001
CEC (cmolc/kg)	13.5 ± 0.27
OM (%)	3.2 ± 1.32
Texture	Sandy loam
Clay (%)	19.78
Sand (%)	64.73
Silt (%)	15.49

Maize was harvested manually at physiological maturity from a sample quadrat of 2 m x 2 m at 75 days after sowing. The harvesting of maize was done when the majority of the plants have reached the silking stage. At this time, ears were fully developed, the husk leaves remain tight and had a good green appearance and the kernels were still milky, soft and 70-75% water content. Data recorded include plant height, cob length, number of kernels per cob, 1000 kernel weight, green cob weight, green cob yield (kg/ ha), biomass yield (kg/ha) and harvest index (HI). The grain quality parameters such as, protein content, sugar content and oil content were determined. Data were analyzed with the analysis of variance (ANOVA) procedure using SAS version 9.3. Duncan's Multiple Range Test (DMRT) was used to compare treatment means at 0.05% probability levels.

RESULTS AND DISCUSSION

The result showed that there were significant differences among treatments for plant height of maize (Table 3). All fertilizer treatments gave taller maize compared to the control (94.3 cm). The tallest plants were observed under sole application of NPK fertilizers (203 cm) and combined application of soybean residue + 100% PK fertilizers (204 cm). Among treatments with incorporation of crop residues but without fertilizer application, the tallest plant was observed in treatments with soybean residue (143 cm) followed by maize + soybean residue (118 cm) and maize residue (105 cm). The tallest growth of the maize from a combined application of soybean residue + 100 PK fertilizer might be due to the better availability of soil N possibly resulting from the decomposition of the incorporated soybean residue. A similar finding was reported by Kravchenko and Thelen (2007) who indicated that addition of crop residues improved plant growth and plant height of corn. In addition, the tall growth of the maize under 100% NPK was due to

Table 2: Nutrient composition of the residues (n=3 ±SE)

Type of residue	N (%)	P (%)	K (%)	C (%)	C:N
Maize	1.18±0.03	0.34±0.02	0.69±0.02	41.5±0.43	35.3±1.32
Soybean	3.07±0.24	0.62±0.02	1.00±0.23	37.2±0.63	12.3±0.74
Maize + soybean	2.02±0.45	0.50±0.2	0.81±0.23	40.3±0.64	20.6±4.59

Table 3: Effect of crop residues and inorganic fertilizer on agronomic and yield traits of maize

Treatment	PH (cm)	CL (cm)	NK/C	TKW (g)	GCW (g)
Control	94.3e	20.6d	283f	286d	200e
100% NPK	203a	37.2a	684a	519a	560a
Maize residue	105de	20.8d	328ef	286d	208e
Maize residue + 100% PK	172b	23.3c	623b	325c	308cd
Soybean residue	143c	25.0bc	408d	353c	325c
Soybean residue + 100% PK fertilizers	201a	34.8a	683a	509a	550a
Maize + soybean residue	118d	22.0c	369de	302d	259d
Maize + soybean residue + 100% PK	177b	28.5b	551c	408b	432b
LSD (P<0.05)	16.6	2.35	57.8	63.7	
SDE	4.09	1.30	19.68	18.5	11.5
CV(%)	4.64	8.35	7.4	8.32	5.57

Means in the same column followed by the same letters are not significantly different (DMRT $_{0.05}$), PH = plant height, CL =cob length, GCW= green cob weight, NK/C = number of kernels per cob, TKW = thousand kernel weight

the fact that nutrients were released early from the inorganic fertilizer and maize being a destructive feeder could use it for its growth.

Yield components such as cob length, number of kernels per cob, 1000-kernel weight and green cob weight were significantly affected by the treatments (Table 3). The highest cob length (37.2 cm and 34.8 cm), number of kernels per cob (684 and 683), 1000-kernel weight (519 and 509 g) and green cob weight (560 g and 550 g) were obtained from application of 100% NPK and combined application of soybean residue + 100% PK fertilizer, respectively. This indicated that N mineralization from the soybean residue was equal in amount to the inorganic N fertilizer applied in the 100% NPK treatment.

Soybean residue without PK fertilizers gave lower cob length (25.0 cm), number of kernel per cob (408), thousands kernel weight (353g) and green cob weight (325 g) than soybean residue + PK which implied that either N mineralization from soybean residue was restricted without P and K or that P or K was limited in soybean residue. The result is in line with Aulakh (2010) who reported higher yield components in the incorporation of groundnut crop residues in combination with inorganic fertilizers. Further, application of sole maize residue gave cob length (20.8 cm), 1000-kernel weight (318 g), number of kernels per cob (286 g) and green cob weight (208 g) that were not significantly different (P>0.05) from control. The absence of any improvement in yield component from the incorporation of maize residue indicates that expecting a N credit from maize residue to a subsequent maize crop may be unrealistic and maize residue should not be promoted for short term yield benefits. Maize residues contribute little amount of N to the soil due to their wide C:N ratios and the slower decomposition. However, when maize residue was supplemented with PK fertilizer, the growth and yield were increased. This was probably attributed to the faster rate of decomposition of maize as a result of PK fertilizer or that P and K was limiting in maize residue. The same result was obtained by Enriquez et al. (1993) who confirmed that the decomposition rate of crop residue increased with both inherent N and P, and the addition of N and P fertilizer, respectively.

Marketable cob per hectare, green cob yield, biomass yield, and harvest index of maize were significantly affected by treatments (Table 4). Among all treatments, the combined application of soybean residue + 100% PK fertilizer gave marketable cob (61,867), green cob yield (36,500 kg/ha), biomass yield (44,550 kg/ha), and harvest index (82%) that were not significantly different (P>0.05) from 100% NPK. This implies that incorporation of soybean residue was able to substitute for inorganic N fertilizer. This was probably due to higher N availability caused by greater mineralization of N from soybean residue. This result is consistent with Khan *et al.* (2008) who reported that returning of soybean residue without applying N fertilizer increased the subsequent wheat yield by 44.9%. In contrast, application of sole maize residue did not result in any improvement from control (P>0.05) in marketable cobs (31,437, and 35,084, respectively), green cob yield (10,323 kg/ha and 11,237 kg/ha, respectively), biomass yield (18,527 and 21,377 /ha, respectively) and harvest index (56% and 52% respectively) of maize, showing that maize residue was an ineffective fertilizer over the short term. Again, incorporation of soybean residue without addition of P and K fertilizer showed poorer performance of maize compared to the soybean residue with P and K fertilizer. This indicated the important contribution of P and K fertilizer in order to realize the benefit of the soybean residue. This might be due to the P and K content in soybean residue was not enough to meet the crop requirement (Table 2). This result is in line with Abbasi *et al* (2009) who reported that the dry matter yield of maize was higher in addition of crop residues + P fertilizer than crop residue alone.

The high harvest index (HI) obtained from the combined application of crop residue and inorganic fertilizer treatments was due to efficient utilization of nutrients, which increased the rate of conversion of dry matter into economic yield. Also, the increase in kernel per cob and better green cob yield in the combined application of organic and inorganic fertilizer led to a higher HI. These results are in

Table 4: Effect of organic manure residues and inorganic fertilizer on yield characteristics of maize

Treatment	MC/ha (no.)	GCY (kg/ha)	BY (kg/ha)	HI (%)
Control	31,437d	10323f	18627d	0.56c
100% NPK	61,045a	37290a	47645a	0.78a
Maize residue	35,084d	12570ef	19143d	0.60bc
Maize residue + 100% PK	46,672c	25217c	36470b	0.69ab
Soybean residue	44,972c	17173d	25962c	0.69abc
Soybean residue + 100% PK fertilizers	61,867a	36167a	46317a	0.78a
Maize +soybean residue	44,289c	14020e	21222cd	0.67abc
Maize + soybean residue + 100% PK	55,604b	29620b	39058b	0.76a
LSD (P<0.05)	5557	2399	4861	0.13
SDE	2701	729	1079	1.9
CV(%)	9.8	5.7	5.89	4.98

Means in the same column followed by the same letters are not significantly different ($DMRT_{0.05}$), MC=marketable cobs, GCY= green cob yield, BY= biomass yield, HI= harvest index

agreement with Kumbhar *et al.* (2007) who reported an optimum grain yield, biomass yield and higher HI of wheat that was grown after legume.

Among incorporation of crop residues without inorganic fertilizers, the highest marketable cobs (44,972), yield (17,173 kg/ha) and harvest index (0.69) were observed in application of soybean residue followed by maize + soybean residue and maize residue (Table 4). The benefit of the maize crop from the previous cropping with different crop differed widely according to the nature of the crop residues. This was probably due to differences in residue N content. The increased yield under the incorporation of soybean residue compared to maize + soybean residue and maize residue might be due to the higher N content of soybean residue. This leads to more rapid N mineralization which resulted in an earlier N release peak. Incorporation of organic source which has a narrow C: N ratio could release sufficient mineral N that met crop requirements while high C:N ratio organics could not release enough N to meet crop requirement. The results are in agreement with Torres *et al.* (2015) and Yusuf *et al.* (2009) who reported incorporation of soybean residues improved the N uptake and grain yield of the subsequent maize compared to the incorporation of maize residues in continuous maize based cropping system. The increased yield of maize in maize + soybean residue over sole maize residue was due to the presence of soybean which raised the N content of the residue. Vachon and Oelbermann (2011) reported that a mixture of residues with low and high N content supply a considerable amount of nutrients to the plant over the short-term and sustain organic matter over the long-term.

Grain quality: Sole and combined application of crop residue and inorganic fertilizer had a significant effect on sugar, protein and oil content of maize (Table 5). All fertilized treatments gave a better protein content of maize than the control. Among fertilizer treatments, the highest protein content was observed in combined application of soybean residue + PK fertilizer (16.5%), but it was not significantly different (P>0.05) from the NPK fertilizer treatment (14.0%). The balanced nutrient supply through soybean residue and inorganic fertilizer might help in more efficient translocation of nitrogen from the vegetative part to the seeds and increase the activity of nitrate reductase in protein synthesis. The result is in accordance with Abedi *et al.,* 2010 and Zafar *et al.* (2011) who reported significantly higher protein content in a combination of inorganic and organic sources and inorganic fertilizer alone. Incorporation of soybean residue resulted in better protein content of maize than incorporation of maize residue. This was due to the higher N content of soybean. Nitrogen, being the main component of protein might have considerably increased the protein content of kernel due to increased uptake of nitrogen under higher N level of soybean residue.

Table 5: Effect of organic manure residues and inorganic fertilizer on grain quality of maize

Treatment	Protein content (%)	Sugar content (^{0}brix)	Oil content (%)
Control	8.30e	9.00d	4.77d
100% NPK	15.2ab	15.4a	6.00abc
Maize residue	11.1d	10.9c	4.77d
Maize residue + 100% PK	12.9c	12.8b	5.63d
Soybean residue	13.8bc	13.3b	5.30cd
Soybean residue + 100% PK fertilizers	16. 5a	16.3a	6.30ab
Maize +soybean residue	13.2c	11.0c	4.90d
Maize + soybean residue + 100% PK	14.0bc	15.1a	6.67a
LSD (P<0.05)	1.7	2.29	0.85
SDE	0.57	0.71	0.27
CV(%)	7.57	9.75	8.47

Means in the same column followed by the same letters are not significantly different ($DMRT_{0.05}$)

The highest sugar content of maize was observed in combined application of soybean residue + PK, maize + soybean residue + PK and sole application of NPK. In contrast, the lowest sugar content was observed in control treatment. The high nutrient level in the above treatments resulted in a higher content of sugar, indicating the importance of nutrients in enhancing sugar content. This implies high starch metabolism and better translocation of carbohydrate to the growing part (Ibrahim *et al.,* 2013). The finding of this experiment is similar to Kumar *et al.* (2010) who found higher sugar content of sweet corn and sweet sorghum, respectively in organic and inorganic fertilizers.

The highest oil content was observed in combined application of maize + soybean residue + PK, but was not significantly different (P>0.05) from combined application of soybean residue + PK and application of NPK. Sole application of crop residue did not give increased oil content of maize over control. The highest oil content in a combination of crop residue and PK fertilizer might be due to the synthesis of higher fatty acid through the pentose phosphate pathway in the seeds. In addition, the increased oil content of maize was attributed to the improved sulfur content of the soil. This finding collaborates with Esmaeilian *et al.* (2012) reported the highest protein and oil content in 50% cattle manure + 50% chemical fertilizer over sole application of cattle manure and chemical fertilizer. Anwar *et al.* (2005) also reported that the combination of Vermicompost at 5 t ha^{-1} + fertilizer NPK 50:25:25 kg ha^{-1} gave higher oil content than sole application organic and inorganic fertilizer.

CONCLUSION

Based on the result, sole and combined application of crop residue with inorganic fertilizer gave a significantly higher yield and grain quality than that of the control. The incorporation of soybean residue or maize + soybean residue managed to increase maize yield without additional N fertilizer. On the other hand, the incorporation of maize residue alone gave no increase in yield over the control. Among the treatments, the combined application of soybean residue + PK fertilizer increased maize yield to the same level as NPK fertilizer. Organic residues such as crop residue are cheap and easily available sources of nutrients for smallholder farmers compared to expensive inorganic fertilizer and also they are environmentally friendly. Therefore, substitution of N fertilizer with soybean residue and application of PK inorganic fertilizer is recommended to increase yield and grain quality of maize.

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