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Application of mungbean residue as green manure. III. Effects on some quality characteristics of sweet potato

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ABSTRACT

Incorporating green manure in soil increases the availability of nutrient elements and improve of quality characteristics in the succeeding crops. So, a field experiment was conducted at the experimental farm and laboratory of Institute of Sustainable Agrotechnology, Universiti Malaysia Perlis, Padang Besar, Perlis, Malaysia. This study was about effect of green manure with mungbean (*Vigna radiata* L.) on some quality characteristics of sweet potato under two grown conditions; open field and greenhouse. The green manuring of mungbean was compared with the control. Results of the study show of that there were different effect of treatments on quality characteristics of sweet potato. The highest nitrogen content in leaves and protein content in tuberous root 1.64% and 2.49%, respectively, were observed in the treatment of mungbean residue. But the highest sugar content of 19.93% in tuberous root was recorded in control treatment. Mungbean residue and control treatment were not significantly different between them in phosphorous and potassium content in leaves, hardness of tuberous root and starch content. There was significant increment in nitrogen and potassium contents in sweet potato leaves under open field condition. On the other hand, there was significant increment in sugar content under greenhouse condition. But the different conditions were at par in phosphorous content in leaves, starch content in tuberous root and hardness of tuberous root. The nitrogen content in leaves was greatest at treatment of mungbean residue under open field condition, while treatment of mungbean residue under greenhouse condition gave highest protein content in tuberous root compared to other treatments. Highest starch content and sugar in tuberous root were found in control treatment under greenhouse condition 52.90% and 20.92%, respectively.

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INTRODUCTION

Organic fertilizers are indispensable for vegetable cultivation, especially in regions that suffer from low organic matter content. This production arrangement is a significant priority area worldwide in view of the increasing demand for healthy and safe food and long-lasting sustainability in addition to matters regarding environmental pollution. In this system, production is based on synergism with nature, which accounts for its sustainability (Mahdi et al., 2010). Though the usage of chemical inputs in farming is unavoidable to meet the growing requirements for feed and food in the world, presently there are opportunities for certain crops and niche regions for successful organic farming. Sustainable nutrient control is very essential. This necessitates a series of management practices to preserve soil resources, retain or enhance productivity and facilitate the reduction in farmers' reliance on expensive chemical fertilizers. One of the important components

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of the sustainable system is the use of legume rotation crops and/or organic soil amendments such as green manure.

Mungbean (*Vigna radiata* L.) is an important crop of the summer period with several uses. It finds usage in soil reclamation, green manuring, and animal feed. Green manuring is the procedure of growing crops, ideally legumes, and plowing them beneath the soil surface. It can improve the sustainability of the farming system by protecting the soil from erosion, improving fertility and also enhancing soil properties. Also, it may improve nutrition of subsequent crops using several mechanisms. Green manure crops are grown to be directly incorporated into the soil for the purpose of enriching it. It has been demonstrated that legume green manures can: provide a significant source of nitrogen to the subsequent crop plant by converting the unreactive form of nitrogen in the air (N₂) to reactive forms of nitrogen (NH₄ and NO₃) that can be utilized by plants (MacDicken, 1994). Recycle nutrients from the subsoil (Hartemink et al., 1996) and prevent root decay, thus replacing some portion of economically and environmentally costly chemical fertilizers (Maroko et al., 1998).

However, there is a lack of known information on the effects of mungbean residue on the quality characteristics of sweet potato plants, especially on the actual correlation between the effects of mungbean residue on the soil and on the successful development of the plants. Therefore, the objectives of this study were to assess the potential of mungbean residue as a green manure and its effects on the quality characteristics of sweet potato plants under different growth conditions.

MATERIAL AND METHODS

Experiment Site:

This field experiment was conducted from 16th July to 17th September 2016 at the Institute Sustainable Agrotechnology (INSAT) experimental farm, Universiti Malaysia Perlis, Padang Besar, Perlis, Malaysia. Geographically, it is situated at the coordinates of 6.6530 N, 100.2610 E with an average altitude of 1,800 m above sea level and the area receives an average annual rainfall of 1700-2200 mm. The annual average air temperature at the study site was about 32 °C. The mean maximum and minimum air temperatures during the experimentation period were 26.6 and 27.7 °C, respectively, at open field and 30.53 and 31.9 °C, respectively, at greenhouse. The experiments were set up on loamy sand soil. Soil pH was 5.5–6.5, and catalogued as chromic luvisol as per the FAO/UNESCO legend (Asiamah, 1998). The data associated with the soil properties and the green manure is displayed in Table 1. The humidity, temperature and rainfall of the research field are summarised in Table 2 and Fig. 1.

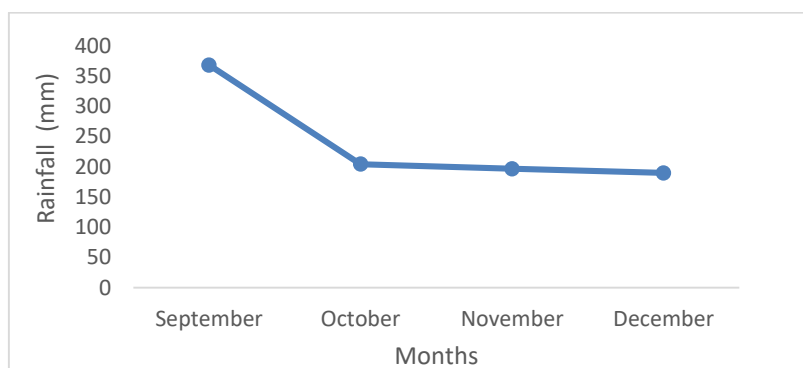
Table (1) Some properties of applied soil and plant residue in this study

Parameters	Unit	Soil	Mungbean residue
Sand	(%)	80.2	-
Silt	(%)	9.6	-
Clay	(%)	7.6	-
Textural class	Loamy sand		-
CEC	(%)	25	-
pH		5.9	5.2
N	(%)	0.15	3.6
P	(ppm)	46	2440
K	(%)	0.20	29.6
Mg	(%)	0.73	11
OC	(%)	0.12	27
OM	(%)	2.2	79
C:N		1.64	6.75

*CEC= cation exchange capacity; N = nitrogen; P = phosphorus; K = potassium; Mg= magnesium; OC= organic carbon; OM = Organic matter

Table (2) Mean values of weather parameters recorded during study season

Month	Parameters	Open field	Greenhouse
September	Temperature (°C)	27.7	31.9
	Relative humidity (%)	76.67	72.86
October	Temperature (°C)	27.1	30.53
	Relative humidity (%)	85.54	82.29
November	Temperature (°C)	27.4	31.11
	Relative humidity (%)	83.58	81.48
December	Temperature (°C)	26.6	31.78
	Relative humidity (%)	85.8	84.95

**Figure (1) Mean values of rainfall recorded during study season**

The soils were treated with no residue (control) and mungbean residue. A local sweet potato cultivar was used. The fresh mungbean residue was harvested from the field 1 month after it was planted. The experimentation in greenhouse was carried out in greenhouse 12 × 44 m having side ventilation. Meanwhile the research in open field was carried out in a flat and homogeneous area. The land area used for the experiment had dimensions of 63 m² (9 m × 7 m). The replicates were separated from each other by 1.30 m lanes, while the individual sections were separated by 0.4 m lanes. The experimental outline was a split-plot model with 4 replicates. The major plots were allotted to open field and greenhouse and the smaller plots to green manure and control.

The mungbean residue was incorporated into the soil immediately within 1 week after ploughing. Seventy tons per hectare of fresh mungbean were evenly spread on the appropriate plots and incorporated into the soil with a hand hoe. The sweet potato cuttings were planted four weeks after the application of the mungbean residue. The cuttings were directly planted using a stick to push them into the soil. Each cutting was planted at a spacing of 40 cm × 150 cm, thereby giving a plant population of 26,666 plants per hectare.

Analysis of Quality Characteristics

The sweet potato parts (shoots and tuberous root) were collected and dried at 70°C in an oven for three days, and their dry weight was then determined. The analysis of the total nitrogen content was conducted using the Kjeldahl method. It was then multiplied by 6.25 to determine the protein content. The analysis of the phosphorous and potassium content was conducted using a UV-spectrophotometer and atomic absorption spectrophotometer, respectively. The Lane and Eynon's method was used to analyse the starch and sugar content (AOAC, 2005).

Statistical Analyses

Data was analysed with ANOVA as a split-plot randomized complete block design, with four replications. When significant statistical interactions between condition and mungbean residue were found, a t-test was performed. Data was analysed using SAS, version 9 (SAS Institute, 2002).

RESULTS AND DISCUSSION

Effect of mungbean residue, different growth conditions and interaction between them on nitrogen content in sweet potato leaves

The high uptake amounts of nitrogen in leaves of sweet potato 1.64% was found in the mungbean residue treatment (Table 3). Most studies on green manure are related to leguminous

crops, which present a high potential to atmospheric N fixation and availability to subsequent crops, as was observed in this study for mungbean. Efficiency and utilization of N were greater following these legume green manure crops than following either fallow or wheat (Badaruddin and Meyer 1990). Griffin and Hesterman (1991) and van Cingel (1992) also found an increase in potato plant N uptake after legume green manure treatments. Mahler and Hermamda (1993) also indicated that winter pea (*Pisum sativum* sp. *Arvense* L.) at 3 Mg ha⁻¹ provided a N credit of 47 to 76 kg N ha⁻¹ to spring wheat. However, this study indicated that other green manure species (Cruciferae and Graminae) significantly increased wheat yields and N uptake. These results indicate that benefits of green manures consist of recovery of residual soil N or by fixing atmospheric N and their N contribution to a subsequent crop.

Table (3) Effect of mungbean residue on nitrogen content in sweet potato leaves

Treatments	(%)		Mean
	Open field	Greenhouse	
Control	1.86 a	1.06 c	1.46 b
Mungbean residue	1.93 a	1.35 b	1.64 a
Mean	1.89 a	1.20 b	

* Different alphabets in the same column show significant difference using Duncan's Multiple Range test ($P \leq 0.05$) and average was calculated from four replicates.

The nitrogen uptake of 1.20% under greenhouse conditions was considerably lower than the nitrogen uptake of 1.89% in open field conditions (Table 3). A high temperature above the optimum point (21-26 °C) (Nedunchezhiyan et al., 2012), can limit photosynthesis and photosynthetic potentials (Taub et al., 2000; Crafts-Brandner and Salvucci, 2002; Wollenweber et al., 2003; Ristic et al., 2009). On the other hand, deterioration will be accelerated when leaves eventually become older, subsequently decreasing photosynthetic activity (He et al., 2002; Plaut et al., 2004). The lack of photosynthetic capacity at elevated temperature is attributed to enhanced leaf deterioration (Jiang et al., 1999; Mohanty, 2003). The mature leaves of maize crops have low nitrogen matter compared to the younger leaves, suggesting that old leaves deteriorate more profoundly (He et al., 2002), as verified by the present research. Compared with older tobacco crops, chlorophyll fluorescence imaging conducted on younger plants showed a higher photosynthetic ability at the plant level (Lefebvre et al., 2005).

The nitrogen content in the sweet potato leaves varied from 1.06% under the control treatment in greenhouse conditions to 1.93% for the mungbean residue treatment in open field conditions (Table 3). The nitrogen concentration in the sweet potato leaves under different treatments in decreasing order was mungbean residue in open field > control in the open field > mungbean residue in the greenhouse > control in the greenhouse. These results were consistent with the hypothesis that the characteristics of the site and/or the weather reduce the availability of nitrogen from green manure residues (Plotkin, 2000). These results were consistent with the amount of above ground biomass of sweet potato produced using mungbean residue because the soil that was incorporated with mungbean residue gave the highest above ground biomass of sweet potato, and the greater amount of plant nutrients in these residues might have had a subsequent result on the sweet potato plants that were grown after that.

Effect of mungbean residue, different growth conditions and interaction between them on phosphorous content in sweet potato leaves

The results of phosphorous content in sweet potato plants grown under different treatments are presented in Table 4. Phosphorus content in leaves of sweet potato was not affected in both conditions, treatments of mungbean residue and interaction among them. These results, differing from that of Khan et al. (2010) proved that the highest P consumption by the wheat leaves was found in the green manure processing, while the lowest P consumption was measured in the control treatment.

Table (4) Effect of mungbean residue on phosphorous content in sweet potato leaves

Treatments	(%)		Mean
	Open field	Greenhouse	
Control	0.27 a	0.26 a	0.265 a
Mungbean residue	0.31 a	0.26 a	0.285 a
Mean	0.29 a	0.26 a	

* Different alphabets in the same column show significant difference using Duncan's Multiple Range test ($P \leq 0.05$) and average was calculated from four replicates

Effect of mungbean residue, different growth conditions and interaction between them on potassium content in sweet potato leaves

Mungbean residue application had no impact on potassium content in leaves of sweet potato compared with control (Table 5).

Table (5) Effect of mungbean residue on potassium content in sweet potato leaves

Treatments	(%)		Mean
	Open field	Greenhouse	
Control	2.97 a	2.35 b	2.66 a
Mungbean residue	2.75 a	2.77 a	2.76 a
Mean	2.86 a	2.56 b	

* Different alphabets in the same column show significant difference using Duncan's Multiple Range test ($P \leq 0.05$) and average was calculated from four replicates

A higher content of potassium in sweet potato leaves was obtained from the sweet potato plants in the open field compared to the plants in the greenhouse (Table 5). Hood and Mills (1994) found that the use of K by snapdragon (*Antirrhinum majus* L.) plants improved as root area temperature was raised from 8°C to 29°C, but absorption of K decreased as root area temperature was raised from 29°C to 36°C.

The effect of the mungbean residue on the potassium content in the sweet potato leaves was significant in both conditions (Table 5). The effect of the control treatment on the potassium content was also significant in the open field conditions, while the control treatment gave the lowest potassium content of 2.35% under greenhouse conditions. The accumulation of nutrient stores enables the plant to grow when water, temperature, and radiation are most favorable for growth and buffers the plant from day-to-day dependence upon available soil nutrients (WJeffrey, 1964). Also, Plants adapted to other stresses such as drought, salinity, shade, and low temperature also grow slowly and share many of the basic characteristics of plants adapted to infertile soils, reinforcing the concept of interdependent physiological characteristics constituting a stress-tolerant adaptive strategy. This is considering that nutrient and shade stress develops concurrently through succession (Grime, 1977; Chapin and Van Cleve, 1979; Grime, 2006).

Effect of mungbean residue, different growth conditions and interaction between them on hardness of tuberous root

The mungbean residue, conditions and interactions did not have any impact on the hardness parameter (Table 6).

Table (6) Effect of mungbean residue on hardness of tuberous root

Treatments	Kg/cm ²		Mean
	Open field	Greenhouse	
Control	14.49 a	14.41 a	14.45 a
Mungbean residue	13.94 a	15.51 a	14.72 a
Mean	14.21 a	14.96 a	

* Different alphabets in the same column show significant difference using Duncan's Multiple Range test ($P \leq 0.05$) and average was calculated from four replicates

Effect of mungbean residue, different growth conditions and interaction between them on protein content in tuberous roots

The protein content in the tuberous roots of sweet potato increased to more than 16.9% on average in the plants cultivated in mungbean residue compared to the control treatment (Table 7). These results suggested that the protein content in tuberous roots of sweet potato was significantly dependent on the nitrogen content in the mungbean residue (Tables 1 and 3). These results were in agreement with the findings by Maiksteniene and Arlauskiene (2004).

Table (7) Effect of mungbean residue on protein content in tuberous roots

Treatments	(%)		Mean
	Open field	Greenhouse	
Control	1.95 c	2.32 b	2.13 b
Mungbean residue	2.42 ab	2.57 a	2.49 a
Mean	2.18 a	2.44 a	

* Different alphabets in the same column show significant difference using Duncan's Multiple Range test ($P \leq 0.05$) and average was calculated from four replicates

The different growth conditions had no effect on the protein content (Table 7).

Generally, the plots treated with mungbean residue had significantly higher protein content than where mungbean residue treatments were not applied (Table 7). The mungbean residue under greenhouse condition specifically had liming effect on tuberous roots to the highest protein content detected on the treatments 2.57%. The large variations in protein content, in addition to genetic factors and applied cultural practices, these characteristics were also affected by the agroecological factors of the location. Similar results were obtained by Vidić et al. (2010) and Popović et al. (2012). Also, According to Tester et al. (1991) and Savin and Nicolas (1996) stress from high temperature during grain filling can result in higher protein levels, at least for daily maximum temperatures above 30 °C. Other stresses, such as shading, could also result in higher protein contents than expected (Marinissen and Grashoff, 1994; Boonchoo et al., 1998).

Effect of mungbean residue, different growth conditions and interaction between them on starch content in tuberous roots

The mungbean residue and conditions had no effect on the concentration of starch in the tuberous roots of sweet potato (Table 8). However, the interactions between them had an effect on the starch concentration in tuberous roots. The control treatment in the open field tended to produce a lower amount of starch (51.22%) compared to that produced by the other treatment (Table 8).

Nonetheless, the effects of treatment on starch content were not constant between different conditions, and some mungbean residue treatment had lower amounts than control. This was interpreted as a result of the nitrogen in the soil that was released during the decomposition of the mungbean residue plants. Consequently, the nitrogen content could have enhanced the vegetative plant growth rather than increased the starch content in tuberous roots (Nakviroj et al., 2002;

Westerman, 1990). Results show significant increase in starch content in tuberous roots of sweet potato under greenhouse condition. Probably, incorporation of mungbean residue may have had little effect on starch content, due to legume residues decompose very quickly when ploughed under in warm, moist conditions, with Slight effects on soil properties (Tate, 1987).

Table (8) Effect of mungbean residue on starch content in tuberous roots

Treatments	(%)		Mean
	Open field	Greenhouse	
Control	51.22 c	52.90 a	52.06 a
Mungbean residue	51.77 bc	52.50 ab	52.13 a
Mean	51.49 a	52.70 a	

* Different alphabets in the same column show significant difference using Duncan's Multiple Range test ($P \leq 0.05$) and average was calculated from four replicates

Effect of mungbean residue, different growth conditions and interaction between them on sugar content in tuberous roots

Table 9 shows that sugar content in tuberous roots of the sweet potato plants under control treatment was higher than in tuberous roots of the plants in the mungbean residue treatment. Mungbean residue could have caused excessive discharge of carbon dioxide (CO₂) and possibly nitrate (NO₃⁻) into the soil, causing reduced pH. Surplus N and P present in the soil and acidity could lead to nutrient disproportion in sweet potato which results in the reduction in the consumption of certain nutrients (Eghball, 2002; Obi and Akinsola, 1995). Hence, it was observed in this research that percentage of sugar in sweet potato was decreased in mungbean residue. This outcome disagrees with (Caceres and Alcarde, 1995) who found an average increase of sugar due to green manure crops grown before sugarcane.

Table (9) Effect of mungbean residue on sugar content in tuberous roots.

Treatments	(%)		Mean
	Open field	Greenhouse	
Control	18.95 b	20.92 a	19.93 a
Mungbean residue	17.32 b	17.52 b	17.42 b
Mean	18.13 b	19.22 a	

* Different alphabets in the same column show significant difference using Duncan's Multiple Range test ($P \leq 0.05$) and average was calculated from four replicates.

During sweet potato harvest, increases in sugar concentration was observed in tuberous roots of plant planted under greenhouse condition more than tuberous roots of plant planted under open field condition (Table 9). Ravi et al. (2009) suggested that low storage root yield could be attributed to the lack of sucrose translocation and starch synthesis under different conditions. Both air and soil temperature regulate the competition between shoot and storage root growth in sweet potato. Likewise, Kocsis et al. (2008) and Badea and Basu (2009) found that high temperatures increased sugar content.

The control plants cultivated under greenhouse condition had the highest sugar content, while the plants cultivated in mungbean residue under open field conditions had the lowest value (Table 9). No differences were observed among the plants subjected to the control treatment in the open field and the mungbean residue treatment in both greenhouse and open field. The negative relationship between N-supply and fruit sugar contents could be supported by the results obtained by El -Shal et al. (1993) and Ghoneim et al. (2003), who stated that the higher N application produced fruits with lower sugars content. The opposing ramifications of N on sugar content could

be credited to the fact that under high N amount, greater content of carbohydrates possibly directed and used in maintaining strong vegetative growth and a small proportion may be used to supply the developing fruits with adequate carbohydrates.

CONCLUSIONS

In this study, mungbean residue, different conditions and interaction between them had different effects on quality parameters attributes. While mungbean residue gave the highest effect on nitrogen content in leaves and protein content in tuberous roots, it did not effect on phosphorous and potassium contents in leaves, hardness of tuberous roots and starch content in tuberous roots. However, mungbean residue adversely affected sugar content in tuberous roots. Nitrogen content in leaves and potassium content in leaves increased significantly when the temperature increased from 26.6°C to 27.7°C (under open field condition) when compared when the temperature increased from 30.53°C to 31.9°C (under greenhouse condition). There was no significant different between conditions of open field and green house in phosphorous content in leaves, protein content in tuberous roots and starch content in tuberous roots. On the contrary, sugar content in the tuberous roots under greenhouse condition was higher than sugar content under open field condition. Mungbean residue under open field gave highest nitrogen content in leaves, while under greenhouse condition gave highest protein content in tuberous roots, whereas control treatment under greenhouse condition gave significant increment in starch and sugar contents.

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استخدام بقايا الماش كسماد أخضر.3. التأثيرات على بعض الخصائص النوعية للبطاطا الحلوة

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الخلاصة

يؤدي دمج السماد الأخضر في التربة إلى زيادة العناصر الغذائية وتحسين نوعية المحصول التالي. أجريت تجربة ميدانية في محطة الأبحاث ومختبرات معهد التكنولوجيا الزراعية المستدامة، جامعة برليس، ماليزيا. لمعرفة تأثير السماد الأخضر (بقايا الماش) (*Vigna radiata* L.) على بعض الصفات النوعية للبطاطا الحلوة تحت طرفين هما الحقل المكشوف والبيوت المحمية. تمت مقارنة السماد الأخضر مع معاملة المقارنة. بينت نتائج الدراسة أن هناك تأثيراً مختلفاً للمعاملات على الصفات النوعية في البطاطا الحلوة. أذ لوحظ أن أعلى محتوى نيتروجين في الأوراق والبروتين في الدرنات (1.64% و2.49% على التوالي) في معاملة بقايا الماش. فيما تم تسجيل أعلى محتوى سكر بنسبة 19.93% في الدرنات في معاملة المقارنة. لم يكن هناك اختلاف معنوي بين بقايا الماش ومعاملة المقارنة في محتوى الفسفور والبوتاسيوم في الأوراق، وصلابة الدرنات ومحتوى النشا. وأوضحت النتائج زيادة معنوية في النيتروجين والبوتاسيوم في أوراق البطاطا تحت ظروف الحقل المفتوح، من ناحية أخرى كانت هناك زيادة معنوية في محتوى السكر تحت ظروف الزراعة المحمية. وفي الوقت ذاته لم يكن هناك أي فرق معنوي بين الزراعة المكشوفة والمحمية في كل من محتوى الفسفور في الأوراق، ومحتوى النشا في الدرنات وصلابة الدرنات. أما بالنسبة للتداخل فقد كان محتوى النيتروجين في الأوراق أعلى في معاملة بقايا الماش تحت ظروف الحقل المكشوف، بينما أعطت معاملة بقايا الماش تحت ظروف الزراعة المحمية أعلى محتوى بروتين في الدرنات مقارنة بالمعاملات الأخرى. وكذلك تم الحصول على أعلى محتوى من النشا والسكر في الدرنات في معاملة المقارنة تحت ظروف الزراعة المحمية (52.90% و20.92% على التوالي).

الكلمات المفتاحية:

صلابة الدرنات، بروتين، سكر، الماش، السماد الأخضر.