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RESEARCH ARTICLE

Growth, Nitrogen and Phosphorus Uptake of Sorghum Plants as Affected by Green Manuring with Pea or Faba Bean Shell Pod Wastes Using ^{15}N

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Abstract:

Background:

During the freezing or canning preparation process of green grain leguminous, large amounts of shell pods are considered as agricultural organic wastes, which may be used as Green Manure (GM) for plant growth enhancement.

Objective:

Evaluation of the effectiveness of soil amended with shell pod wastes of pea (PGM) or faba bean (FGM) as GM on growth, nitrogen and phosphorus uptake in sorghum plants.

Methods:

Determination of the impact of adding four rates of nitrogen (0, 50, 100, and 150 kg N ha^{-1}) in the form of pea (PGM) or faba bean (FGM) shell pod wastes as GM on the performance of sorghum using the indirect ^{15}N isotopic dilution technique.

Results:

Sorghum plants responded positively and differently to the soil amendments with either GMs used, particularly, the PGM. In comparison with the control (N), soil amendment with an equivalent rate of 3.5 t ha^{-1} of PGM (PGM_{100}) or with 6.5 t ha^{-1} of FGM (FGM_{150}) almost doubled dry weight, N and P uptake in different plant parts of sorghum. Regardless of the GM used, estimated values of $\%Ndf_{gm}$ in sorghum plants ranged from 35% to 55% indicating that the use of pod shells as GM provided substantial portions and amounts of N requirements for sorghum. Moreover, nitrogen recoveries of added GM ($\%NUE_{gm}$) ranged from 29 to 45% indicating that N in both of GM forms were used effectively. Accordingly, equivalent amounts to 17 - 48 kg N ha^{-1} of inorganic fertilizer may be saved. The beneficial effect of incorporating pod shells in soil on sorghum N was mainly attributed to their N availability, besides to their effects on the improvement of soil N uptake, particularly when using PGM.

Conclusion:

The agricultural by-products of faba bean and pea pod shells could be used as GM for sorghum growth improvement by enhancing N and P uptake from soil and from the organic source.

Keywords: By-products, Green manure, Leguminous pod shells, ^{15}N, Sorghum, PGM, FGM.

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1. INTRODUCTION

Green Manures (GMs) represent a promising approach to maintaining sustainable nutrients for crop growth [1]. The importance of GM is increasing in recent years because of the high cost of chemical fertilizers, increased risk of environmental pollution, and the need for sustainable cropping systems [2]. Leguminous plants are commonly used as green manure in different cropping systems worldwide. Their residues are particularly useful as organic green manure due to their high nitrogen (N) contents, and because this N is more likely to become readily available for uptake by other plants [3, 4], providing a significant amount of N to the subsequent crop, replacing some portion of the economically and environmentally costly N fertilizers [5, 6]. Therefore, possible options to reduce the use of chemical fertilizers could be the implementation of leguminous plants as green manure in cropping

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systems and recycling of organic wastes [7]. In addition to nitrogen, the GMs also supply other nutrients that are needed for plant growth [8, 9].

To evaluate the benefits of GM for plant production, it is necessary to quantify the proportions and amounts of nitrogen derived from this organic material. The use of the ^{15}N isotope to assess the efficiency of GM fertilizers is extensively reported in the literature. The indirect ^{15}N isotopic dilution technique is widely used to determine the nitrogen fraction derived from GM. This method is based on the fact that plant received un-labeled organic residues (*e.g*. GM) with ^{15}N labeled fertilizer to the soil resulted in a lower ^{15}N in plant tissues compared to the control receiving no residues. This indicates that a dilution effect occurred and that a portion of plant N is derived from GM [3, 10 - 12].

Vicia faba L. (faba bean) and *Pisum sativium* L. (pea) are sources of high-quality protein and are often grown on a large scale worldwide [13]. These grain legumes are the most commonly used legume in the diets of people and can be used as vegetable, green, dried or canned. In Syria, as well as in other Mediterranean regions, seeds of both species are usually consumed green before maturity, after a simple process in which the pod shells are removed. They may be preserved for several months by freezing or canning for later consumption. Disposal of by-products generated by leguminous plant food processing represents a promising source of compounds that may be used for their nutritional properties [14]. During the manufacturing process of canned or frozen grain legumes, like green pea or faba beans, large amounts of shell pods are considered as agricultural organic wastes. Also, substantial amounts of these materials are usually thrown and discarded by housewives during freezing preparation of green grains at home. Effective use of such organic wastes in agriculture could be an important issue in developing countries. These plant materials can be used as unconventional feedstuffs for ruminants [15], or they are thrown away as worthless. On the other hand, Eusuf Zai *et al.* [8] reported that the indigenous agricultural wastes could be recycled and used as GM or compost to achieve the highest nutrient recovery for plant growth enhancement. The ability of grain legumes to fix atmospheric N_2 along with high N content in their tissues with a low C/N ratio would allow their residues 'like shell pods by-products' to make contributions to the N economy in farming systems, particularly in the organic agricultural system [16]. Recently, Fall *et al.* [17] reported that peanut (*Arachis hypogaea*) shells application improved soil chemical properties and tree growth under saline conditions. Thus, the use of such organic wastes, as green manure fertilizers, could be an alternative or additional way for their handling in agriculture. Therefore, the aims of this study were to evaluate the effectiveness of soil amended with shell pod wastes of pea (PGM) or faba bean (FGM) as GM on growth, nitrogen and phosphorus uptake in sorghum plants using the indirect ^{15}N isotope dilution method.

2. MATERIALS AND METHODS

2.1. Soil Properties

The experiment was conducted in pots, each containing 10 kg of soil collected from Deir AL-Hajar research station, locat-ed southeast of Damascus, Syria, (36° 28' E, 33° 21' N) at 617 m above sea level. The area is located within a semiarid region in which the average annual rainfall reaches 120 mm year^{-1}, and most precipitations occur between November and early April. For the last ten years, the average minimum temperature in winter was 1.3°C in January, while it increases to the average maximum temperature of 38.3°C in July. Some climatic data for the studied site collected during the growing season were close to those averaged over the last 10 years (2008 to 2017) as shown in Table **1**. The soil is classified as clay loam, with an average 57.9% clay, 39.5% silt, and 2.6% sand. The main physical and chemical soil properties were pH 7.74; Electrical Conductivity (EC) 0.32 dS m^{-1}; organic matter 0.91%; total nitrogen 0.07%; available phosphorus 6.2 µgg^{-1}; ionic content (meq L^{-1}): chloride (Cl^-) 0.74, bicarbonate (HCO_3^-) 0.97, sulfate (SO_4^{--}) 1.27, calcium (Ca^{++}) 1.15, potassium (K^+) 0.14, sodium (Na^+) 1.27 and magnesium (Mg^{++}) 0.47; Cation Exchange Capacity (CEC) 29.08 meq 100 g^{-1}; nitrate (NO_3^-) 9.5 µgg^{-1} and ammonium (NH_4^+) 6.8 µgg^{-1}.

2.2. Chemical Composition of Green Manure and Treatments

Shell pod wastes of pea (PGM) and faba bean (FGM) were used as a source of Green Manure (GM) for the growth of sorghum plants. After a young pod harvest of pea and faba bean, the green seeds were removed. Pod shells residues of both legumes' species were cut into 3 - 5 cm pieces, weighed, dried, and ground to a fine powder for total N determination by Kjeldahl method, in four replicates. The mean value of total N was 2.3% and 2.86% for faba bean and pea shell pod wastes, respectively. Moreover, total polyphenols in PGM and FGM was determined by the Folin-Ciocalteau method [18]. Lignin was determined using the Acid Detergent Fiber (ADF) method as outlined by Rowland and Roberts [19]. Total carbon in both pod shells was determined by a mass spectrometer (Integra-CN, PDZ Europea Scientific Instrument, UK). Data of polyphenols, lignin, ratio of polyphenols to total N, ratio of lignin /N, ratio of (lignin + polyphenols) to total N and C/N ratio are shown in Table **2**.

Table 1. Some climatic data for the studied site during the experimental period and the last ten years average (from 2008 to 2017).

Year	Variable	July	August	September	October
2008-2017 average	T_{min}(C)	19.7	20.3	18.2	13.9
	T_{max}(C)	38.3	38.0	34.9	29.6
	RH (%)	65.6	64.0	64.2	66.1
	ET (mm day^{-1})	7.1	8.0	6.7	5.3

(Table 1) contd.....

2017	T_{min}(C)	21.3	20.0	18.4	13.0
	T_{max}(C)	40.6	38.5	36.4	28.8
	RH (%)	56.0	59.0	60.0	60.0
	ET (mm day^{-1})	6.4	7.8	5.8	4.9

T_{min}= minimum temperature, T_{max}= maximum temperature, RH= relative air humidity, ET= reference evapotranspiration.

Table 2. Data of total polyphenols (%), lignin (%), ratio of polyphenols to total N, ratio of lignin /N, ratio of (lignin + polyphenols) to total N and C/N ratio in pod shell wastes of faba bean (FGM) and pea (PGM).

Pod shells	Polyphenols (% Ph)	Lignin (L)	C/N	Ph/N	L+Ph/N	L/N
FGM	1.66±0.01^a	32.70±0.57^a	17.96±0.31^a	0.72±0.01^a	14.94±0.26^a	14.22±0.25^a
PGM	0.35±0.01^b	28.30±0.49^b	15.17±0.26^b	0.12±0.003^b	10.02±0.17^b	9.90±0.17^b
LSD $_{0.05}$	0.08	2.08	1.13	0.03	0.87	0.83

Note: Means within a column followed by the same letter are not significantly different (*P*<0.05).

Table 3. Actual amounts of shell pod wastes of pea (PGP) and faba bean (FGP) added as green manure (GM) per pot, in addition to their equivalent rates per unit area.

Treatments	Amounts of Added GM (pot^{-1})		Equivalent Added Rates (ha^{-1})	
	Dry Matter (g pot^{-1})	**Nitrogen**(mg N pot^{-1})	**Dry Matter** (ton ha^{-1})	**Nitrogen**(kg N ha^{-1})
FGM_{50}	9.45	217.4	2.17	50
FGM_{100}	18.9	434.8	4.34	100
FGM_{150}	28.36	652.2	6.51	150
PGM_{50}	7.6	217.4	1.75	50
PGM_{100}	15.2	434.8	3.5	100
PGM_{150}	22.8	652.2	5.25	150

FGP or $PGM_{50,100,150}$: pod shells of faba bean (F) or pea (P) added as GM at rates of 50, 100, and 150 kg N ha^{-1}, respectively.

Pea and faba bean pod shells were incorporated into the soil, fifteen days before sorghum planting, at equivalent rates of 0, 50, 100, and 150 kg N ha^{-1} (Table **3**). They were mixed with the soil of each pot as GM by adopting the following treatments:

- (PGM) or (FGM) control, without green manure (N0).
- (PGM_{50}) addition of shell pod wastes of pea at a rate of 50 kg N ha^{-1} (N50).
- (PGM_{100}) addition of shell pod wastes of pea at a rate of 100 kg N ha^{-1} (N100).
- (PGM_{150}) addition of shell pod wastes of pea at a rate of 150 kg N ha^{-1} (N150).
- (FGM_{50}) addition of shell pod wastes of faba bean at a rate of 50 kg N ha^{-1} (N50).
- (FGM_{100}) addition of shell pod wastes of faba bean at a rate of 100 kg N ha^{-1}(N100).
- (FGM_{150}) addition of shell pod wastes of faba bean at a rate of 150 kg N ha^{-1}(N150).

2.3. Planting Procedures and ^{15}N Application

Seeds of sorghum plants (*Sorghum bicolor* L.) were sown in pots containing soil previously amended with GMs (*i.e.* 15 days before sowing). After germination, seedlings were thinned to two plants per pot. Since soil contained a small amount of available phosphorus, an equivalent amount of 100 kg P_2O_5 ha^{-1} in the form of triple phosphate was applied to the soil prior to planting to all treatments. Pots were weighed every three days and water was added to maintain the soil moisture content at around 75% of field capacity throughout the experimental period. Pots were arranged in a randomized complete block design in four replicates and set outdoors under open field conditions.

To estimate nitrogen derived from green manure, using the indirect ^{15}N isotopic dilution method, an equivalent fertilizer rate of 10 kg N ha^{-1} (43.48 mg N pot^{-1}) in the form of urea enriched with 9.63% ^{15}N atom excess was applied to the soils. The N fertilizer was applied to all treatments in two equally split applications (5 kg N ha^{-1} for each application) at ten days intervals after planting. This procedure was followed to stabilize the ^{15}N enrichment of the N pool and to minimize N immobilization.

2.4. Plant Harvest, Analysis and Calculations

Sorghum plants were harvested 90 days after planting (*i.e.* physiological maturity stage) and separated into shoots, roots, and panicles. Samples were dried to a constant weight at 70 ºC and ground to a fine powder. Kjeldahl method was used to determine total nitrogen in the samples, and the $^{15}N/^{14}N$ isotopic ratio was determined using the emission spectrometry (Jasco-150, Japan). Phosphorus content was determined by dry ashing and measured calorimetrically by spectrophotometer (Termo Specronic, England).

Nitrogen fractions derived from the available sources were calculated using the indirect ^{15}N isotopic dilution method [11, 12, 20] as follows:

The percent N derived from green manure (Ndf_{gm}) for both PGM and FGM was calculated using the following equation:

$\%Ndf_{gm}$= [1-(atom $\%^{15}$N excess $_{treatment}$/ atom $\%^{15}$N excess $_{control}$)]100.

Where treatment: plants amended with PGM or FGM; control: plants grown without any green manure application.

Amount of Ndf_{gm} (mg N pot^{-1}) was calculated as follows:

Ndf_{gm} = ($\%Ndf_{gm}$/100) total N yield.

Nitrogen Use Efficiency ($\%NUE_{gm}$) of added green manure was calculated by the following equation:

$\%NUE_{gm}$= (Ndf_{gm}/N added as GM)100.

Percent (%) and amount (mg N pot^{-1}) of N derived from fertilizer (Ndff) were calculated using the following equations:

%Ndff = (atom$\%^{15}$N in excess $_{plant}$ / atom$\%^{15}$N in excess $_{fertilizer}$)100.

Ndff = (%Ndff/100) total N

Percent (%) and amount (mg N pot^{-1}) of N derived from soil (Ndfs) were calculated as follows:

%Ndfs = 100 - ($\%Ndf_{gm}$ + %Ndff).

Ndfs = (%Ndfs/100) total N.

2.5. Statistical Analysis

Data were subjected to Analysis of Variance (ANOVA) using the statistical program Statview, 4.57® Abacus Concepts, Berkley, Canada. Means were compared using the least significant difference (Fisher's LSD) test at a probability level of P <0.05.

3. RESULTS

3.1. Dry Matter Yield, Nitrogen and Phosphorus Uptake

The data of dry matter yield (DM), nitrogen and phosphorus uptake in different plant parts of sorghum as affected by green manuring with pea pod shell wastes (PGM) are given in Table **4**. Data in the whole plant of sorghum (leaves plus roots and panicles) are shown in Fig. (**1**). The addition of PGM at a rate of 50 kg Nha^{-1} (PGM_{50}), significantly increased total DM yield in sorghum plants as compared with the control. Raising the N rate (*e.g.* 100 and 150 kgNha^{-1}) resulted in more significant increments in the DM, which did not significantly differ from each other. The percent increments in total DM were 60, 99, and 98% in PGM_{50}, PGM_{100}, and PGM_{150}, respectively, as compared with the control PGM. It is noteworthy that DM of panicles increased by 49, 109, and 106% as compared with the control, for the same afore-mentioned treatments, respectively. Also, there were no significant differences in DM between PGM_{100} and PGM_{150} for different plant parts of sorghum. These results may indicate that PGM_{100} is the proper treatment for plant growth improvement. In comparison with the un-manured control treatment, PGM_{100} almost doubled DM in different plant parts of sorghum. The pattern of N yield in sorghum plants was relatively similar to that of dry matter yield. Amounts of nitrogen accumulated in the whole plant of sorghum significantly increased by 63, 123, and 132% in PGM_{50}, PGM_{100}, and PGM_{150}, respectively, as compared with the control. In panicles, the increases were 56, 124, and 126%, for the same treatments. Increasing the rate of nitrogen in the form of PGM from 100 to 150 kg N ha^{-1} did not significantly increase nitrogen yield. Also, total phosphorus content (mg P pot^{-1}) in the different plant parts of sorghum increased as a result of adding PGM. For panicles, the percent increments in total phosphorus content were 77, 185, and 200% in PGM_{50}, PGM_{100}, and PGM_{150}, respectively, as compared with the control PGM (Table **4**). For the whole plant (Fig. **1**), the amounts of P uptake were 86, 142, and 148% higher in PGM_{50}, PGM_{100}, and PGM_{150} than that in the control, for the abovementioned treatments, respectively. No significant difference was obtained between PGM_{100} and PGM_{150} treatments.

For Faba bean pod shells wastes (FGM), soil amended with FGM significantly increased dry matter yield of sorghum (Table **5** and Fig. **1**). Soil amended with FGM at a rate of 50 kg N ha^{-1} (FGM_{50}), significantly increased DM yield in sorghum plants as compared with FGM. Raising the N rate (*i.e.* PGM_{100} and PGM_{150}) resulted in more significant increments in the DM. Percent increments in DM were 19, 103, and 105% for panicles, and 14, 64, and 101% for the whole plant in FGM_{50}, FGM_{100}, and FGM_{150}, respectively, as compared with the un manured control treatment (FGM). Total nitrogen yield by sorghum responded to FGM in a manner relatively similar to dry matter yield. The percent increments in N yield were 29, 111, and 109% for panicles and 21, 69, and 104% for the whole plant, in FGM_{50}, FGM_{100}, and FGM_{150}, respectively. Phosphorus uptake was increased in all plant parts of sorghum as a result of soil incorporated with faba bean shell pod wastes (FGM). FGM increased P yield by 30, 92, and 101%, for the whole plant; and by 37, 156, and 205% for panicles in FGM_{50}, FGM_{100}, and FGM_{150}, respectively, as compared with the control (FGM).

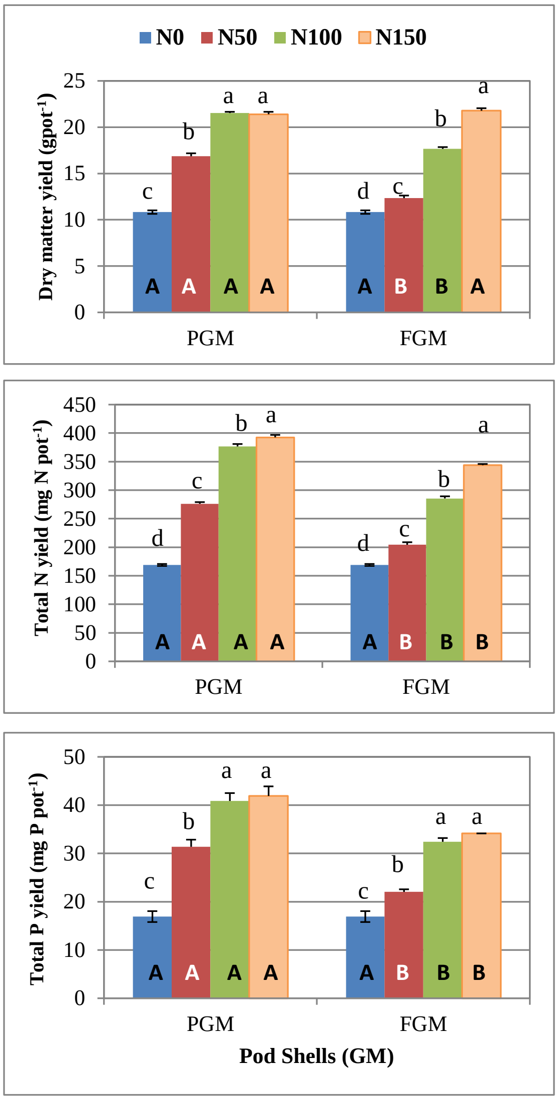

Fig. (1). Dry matter yield (g pot^{-1}), nitrogen (mg N pot^{-1}) and phosphorus (mg P pot^{-1}) uptake in the whole plant of sorghum as affected by green manuring with pea (PGM) or faba bean (FGM) pod shell wastes. Columns followed by the same letter are not significantly different (P<0.05). Small letters above columns: comparison among nitrogen rates for PGM or FGM. Capital letters inside columns: comparison between PGM and FGM for each nitrogen rate.

Table 4. Dry matter (g pot^{-1}), nitrogen (mg N pot-1) and phosphorus (mg P pot^{-1}) yield in different plant parts of sorghum as affected by green manuring with pea pod shell wastes (PGM).

Treatment	Panicles	Roots	Leaves
	Dry Matter Yield (g pot^{-1})		
PGM	1.76 ±0.03^{c}	2.29± 0.07^{c}	6.78±0.10^{c}
PGM_{50}	2.62±0.08 ^{b}	4.43± 0.1^{b}	9.84± 0.32^{b}
PGM_{100}	3.67± 0.08^{a}	5.26 ±0.06^{a}	12.60± 0.01^{a}
PGM_{150}	3.63± 0.09^{a}	5.32 ±0.09^{a}	12.45± 0.09^{a}
$LSD_{0.05}$	0.22	0.25	0.55
	N-yield (mg N pot^{-1})		
PGM	34.0± 1.11^{c}	22.7±0.34 ^{c}	112.2± 1.12^{d}
PGM_{50}	53.1± 1.08^{b}	44.3± 1.50^{b}	187.8± 3.03^{c}

(Table 4) contd.....

PGM_{100}	76.3± 1.36^{a}	54.1±0.36 ^{a}	246.3 ±4.63^{b}
PGM_{150}	77.1± 2.32^{a}	53.9± 0.74^{a}	261.6 ±5.07^{a}
LSD $_{0.05}$	4.78	2.63	11.69
	P-yield (mg P pot^{-1})		
PGM	3.95± 0.31^{c}	3.02±0.19^{d}	9.96 ±0.82 ^{c}
PGM_{50}	7.00±0.70 ^{b}	5.39± 0.14^{c}	19.00± 1.22^{b}
PGM_{100}	11.25 ±0.68^{a}	7.50± 0.26^{a}	23.16±1.15 ^{a}
PGM_{150}	11.84± 0.32^{a}	6.71±0.22 ^{b}	22.27 ±1.77^{ab}
LSD $_{0.05}$	1.65	0.64	3.96

Note: Means within a column followed by the same letter (a,b,c and d) are not significantly different (*P*<0.05). PGM: without GM; PGM_{50}, PGM_{100}, and PGM_{150}: pea pod shells added as GM at rates of 50, 100, and 150 kg N ha^{-1}, respectively.

Table 5. Dry matter (g pot^{-1}), nitrogen (mg N pot-1) and phosphorus (mg P pot^{-1}) yield in different plant parts of sorghum as affected by green manuring with faba bean pod shell wastes (FGM).

Treatment	Panicles	Roots	Leaves
	Dry Matter Yield (g pot^{-1})		
FGM	1.76±0.03^{c}	2.29±0.07^{d}	6.78±0.10^{d}
FGM_{50}	2.10±0.08^{b}	2.85±0.07^{c}	7.40±0.22^{c}
FGM_{100}	3.58±0.04^{a}	4.41±0.11^{b}	9.67±0.16^{b}
FGM_{150}	3.61±0.07^{a}	5.37±0.13^{a}	12.80±0.22^{a}
LSD $_{0.05}$	*0.23*	*0.29*	*0.57*
	N-yeild (mg N pot^{-1})		
FGM0	34.0 ±1.11^{c}	22.7±0.34^{d}	112.2±1.12^{d}
FGM50	44.0±2.48^{b}	28.3±0.89^{c}	131.9±3.50^{c}
FGM100	71.7±1.04^{a}	42.8±0.33^{b}	171.0±4.56^{b}
FGM150	70.9±1.80^{a}	54.4±1.05^{a}	218.8±2.19^{a}
LSD 0.05	5.26	2.24	9.63
	P-yeild (mg P pot^{-1})		
FGM	3.95±0.31^{c}	3.02±0.19^{c}	9.96±0.82^{c}
FGM_{50}	5.43±0.48^{c}	4.20±0.15^{b}	12.41±0.34^{b}
FGM_{100}	10.10±0.27^{b}	5.87±0.51^{a}	16.44±0.96^{a}
FGM_{150}	12.05±0.75^{a}	6.18±0.39^{a}	15.92±0.51^{a}
LSD $_{0.05}$	1.50	1.06	2.16

Note: Means within a column followed by the same letter (a,b,c and d) are not significantly different (*P*<0.05). FGM: control, no green manure; FGM_{50}, FGM_{100} and FGM_{150}: faba bean pod shells added as GM at rates of 50, 100 and 150 kg N ha^{-1}, respectively.

3.2. Nitrogen Uptake from Various Sources

In comparison with the un-manured control plants, soil incorporated with both forms of GM (*i.e.* PGM or FGM), resulted in lower atom %^{15}N excess values in the different plant parts of sorghum (Table **6**). The decrease in ^{15}N in sorghum plants was related to the amount of N in the applied GM. Regardless of plant parts, the highest dilution was obtained in the N_{150} followed by N_{100} and then by N_{50} and N treatments, for both PGM and FGM (Table **6**). Percentages and amounts of nitrogen derived from fertilizer (Ndff), soil (Ndfs), and green manure (Ndf_{gm}) in different plant parts of sorghum as affected by green manuring with PGM or with FGM are shown in Tables **7** and **8**, respectively.

For pea pod shells (PGM) treatments, %Ndff and %Ndfs values in the different plant parts as well as in the whole sorghum plant decreased with increasing rates of the applied PGM (Table **7**). However, the percentage of nitrogen derived from PGM (%Ndf_{gm}) increased with increasing rates of the applied PGM. Values of %Ndf_{gm} in the whole plant of sorghum were 15.7, 48.7, and 53.7% in PGM_{50}, PGM_{100}, and PGM_{150}, respectively. In regard to the amounts of N derived from the available sources, it can be shown from (Table **7**) that soil amendment with PGM generally increased amounts of Ndff and Ndfs, as compared with the control, particularly in PGM_{100}. The percent increments in the amounts of Ndff and Ndfs in the whole plant was about 15% higher than the control in the latter treatment. Moreover, significant amounts of nitrogen were derived from green manure (Ndf_{gm}) which were increased by increasing rates of added PGM. The Ndf_{gm} values in the whole plant of sorghum were 99, 183, and 211 mg N pot^{-1} in PGM_{50}, PGM_{100}, and PGM_{150}, respectively (Table **7**).

For faba bean pod shells (FGM) treatments, the addition of GM addition in the form of faba bean shell pod wastes (FGM) also decreased %Ndff and %Ndfs values. Whereas, %Ndf_{gm} increased with increasing rates of the applied FGM (Table **8**). %Ndf_{gm} values in the whole plant were 37, 48, and 55% for

FGM_{50}, FGM_{100}, and FGM_{150}, respectively. Moreover, it can be shown from Table **8** that the addition of FGM generally decreased the amounts of Ndff and Ndfs in the leaves, panicles, and the whole plant as compared with the control. However, N uptake from both sources (*i.e*. Ndff and Ndfs) increased in roots, particularly in FGM_{100} and FGM_{150}, where the percent increments either in Ndff or Ndfs values were 24 and 40% for both treatments, respectively,

Table 6. Atom $\%^{15}N_{\text{in excess}}$ in different plant parts of sorghum plants manured with pea (PGM) or faba bean (FGM) shell pod wastes.

Treatment	Leaves	Roots	Panicles	Whole plant
	$\%^{15}N_{\text{in excess}}$			
	PGM			
PGM	0.796±0.005^a	0.535±0.005^a	0.764±0.005^a	0.754±0.004^a
PGM_{50}	0.503±0.003^b	0.414±0.005^b	0.483±0.003^b	0.485±0.003^b
PGM_{100}	0.391±0.003^c	0.380±0.004^c	0.381±0.002^c	0.387±0.002^c
PGM_{150}	0.353±0.007^d	0.353±0.005^d	0.334±0.003^d	0.349±0.005^d
$LSD_{0.05}$	0.015	0.014	0.010	0.011
	FGM			
FGM	0.754±0.004^a	0.796±0.005^a	0.535±0.005^a	0.764±0.005^a
FGM_{50}	0.476±0.005^b	0.514±0.006^b	0.379±0.003^b	0.430±0.005^b
FGM_{100}	0.391±0.006^c	0.413±0.002^c	0.351±0.007^c	0.363±0.004^c
FGM_{150}	0.343±0.002^d	0.359±0.005^d	0.314±0.007^d	0.315±0.004^d
$LSD_{0.05}$	0.014	0.017	0.018	0.013

Note: For each green manure type, means within a column followed by the same letter (a,b,c and d) are not significantly different ($P<0.05$). PGM & FGM: control without green manure; PGM & FGM_{50}, PGM & FGM_{100}, and PGM & FGM_{150}: pod shells of pea (P) or faba bean (F) added as GM at rates of 50, 100, and 150 kg N ha^{-1}, respectively.

Table 7. Proportions (%) and amounts (mg N pot^{-1}) of nitrogen derived from fertilizer (Ndff), soil (Ndfs) and green manure (Ndf_{gm}) in different plant parts of sorghum as affected by green manuring with pea pod shell wastes (PGM).

Treatment	Panicles		Roots		Leaves		Whole Plant	
	Ndff							
	mg	%	mg	%	mg	%	mg	%
PGM	2.7±0.1^b	7.93± 0.05^a	1.26±0.02^c	5.55±0.05^a	9.3±0.13^b	8.26±0.05^a	13.2±0.2^c	7.83±0.04^a
PGM_{50}	2.7±0.06^b	5.01±0.03^b	1.90±0.05^b	4.29±0.05^b	9.3±0.19^b	5.22±0.03^b	13.9±0.22^b	5.03±0.03^b
PGM_{100}	3.1± 0.07^a	3.95±0.02^c	2.13±0.02^a	3.94±0.04^c	10.0±0.13^a	4.06 ±0.40^c	15.2±0.12^a	4.02± 0.02^c
PGM_{150}	2.7±0.1^b	3.47±0.03^d	1.96±0.04^b	3.65±0.05^d	9.6±0.33^b	3.66±0.08^d	14.2 ±0.25^b	3.63±0.05^d
$LSD_{0.05}$	0.25	0.11	0.10	0.15	0.65	0.16	0.62	0.11
Ndfs								
PGM	31.3±1.01^b	92.07±0.05^a	21.4±0.35^c	94.45±0.05^a	102.9±1.0^b	91.74±0.05^a	155.7±1.51^c	92.17±0.04^a
PGM_{50}	31.0 ±0.72^b	58.27±0.36^b	32.4±0.78^b	73.11±0.87^b	103.6±2.1^b	57.95±0.34^b	163.6±2.55^b	59.23±0.31^b
PGM_{100}	35.1±0.76^a	45.94±0.23^c	36.3±0.33^a	67.12±0.71^c	111.0±1.4^a	45.07±0.37^c	178.4±1.40^a	47.33±0.19^c
PGM_{150}	31.1±1.13^b	40.29±0.37^d	33.5±0.67^b	62.11±0.81^d	106.5±3.7^{ab}	40.67±0.86^d	167.5±2.90^b	42.67±0.55^d
$LSD_{0.05}$	2.83	0.87	1.74	2.14	7.0	1.54	6.74	1.02
Ndf_{gm}								
PGM	-	-	-	-	-	-	-	-
PGM_{50}	19.5±0.39^c	36.72±0.39^c	10.0±0.71^c	22.59±0.93^c	65.8±1.1^c	36.82±0.37^c	98.7±0.25^c	35.74±0.34^c
PGM_{100}	38.2±0.55^b	50.10±0.24^b	15.7±0.47^b	28.94±0.75^b	125.4±3.3^b	50.87±0.40^b	183.3±2.76^b	48.65±0.20^b
PGM_{150}	43.4±1.15^a	56.26±0.40^a	18.4± 0.5^a	34.24±0.86^a	145.6±2.6^a	55.67±0.94^a	210.8±3.17^a	53.71±0.60^a
$LSD_{0.05}$	2.45	1.13	1.81	2.71	7.96	2.00	7.77	1.32

Note: Means within a column followed by the same letter (a,b,c and d) are not significantly different ($P<0.05$). PGM: without GM; PGM_{50}, PGM_{100}, and PGM_{150}: pea pod shells added as GM at rates of 50, 100, and 150 kg N ha^{-1}, respectively.

Table 8. Proportions (%) and amounts (mg N pot^{-1}) of nitrogen derived from fertilizer (Ndff), soil (Ndfs), and green manure (Ndf$_{gm}$) in different plant parts of sorghum as affected by green manuring with faba bean pod shell wastes (FGM).

Treatment	Panicles		Roots		Leaves		Whole Plant	
	Ndff							
	mg	%	mg	%	mg	%	mg	%
FGM	2.7±0.1^a	7.93±0.05^a	1.26±0.02^c	5.55±0.05^a	9.3±0.13^a	8.26±0.05^a	13.2±0.20^a	7.83±0.04^a
FGM$_{50}$	2.0±0.1^c	4.43±0.05^b	1.11±0.03^d	3.93±0.04^b	7.0±0.26^c	5.34±0.06^b	10.1±0.32^c	4.94±0.05^b
FGM$_{100}$	2.7±0.02^a	3.77±0.04^c	1.56±0.03^b	3.64±0.07^c	7.3±0.30^c	4.28±0.07^c	11.6±0.32^b	4.06±0.06^c
FGM$_{150}$	2.3±0.06^b	3.27±0.04^d	1.77±0.07^a	3.25±0.08^d	8.2±0.07^b	3.72±0.05^d	12.26±0.07^b	3.56±0.02^d
LSD $_{0.05}$	0.24	0.13	0.13	0. 19	0.65	0.17	0.78	0.14
	Ndfs							
FGM	31.3±1.0a	92.07±0.05^a	21.4±0.35^c	94.45±0.1^a	103.0±1.0^a	91.74±0.05^a	155.7±1.51^a	92.17±0.04^a
FGM$_{50}$	22.7±1.30^c	51.49±0.55^b	19.0±0.46^d	66.89±0.6^b	78.1±2.9^c	59.22±0.66^b	118.9±3.81^c	58.20±0.58^b
FGM$_{100}$	31.4±0.25^a	43.78±0.44^c	26.5±0.53^b	61.94±1.3^c	81.3±3.3^c	47.55±0.72^c	136.3±3.77^b	47.76±0.71^c
FGM$_{150}$	26.9±0.64^b	37.99±0.48^d	30.1±1.14^a	55.4±1.27^d	90.4±0.7^b	41.33±0.53^d	144.0±0.82^b	41.85±0.23^d
LSD $_{0.05}$	2.75	1.32	2.12	2.89	6.99	1.71	8.67	1.48
	Ndf$_{gm}$							
FGM	-	-	-	-	-	-	-	-
FGM$_{50}$	19.4±1.12^c	44.07±0.59^c	8.3±0.41^c	29.2±0.60^c	46.7±0.62^c	35.45±0.72^c	75.2±0.42^c	36.86±0.63^c
FGM$_{100}$	37.6±0.86^b	52.46±0.50^b	14.7±0.61^b	34.4±1.33^b	82.2±1.17^b	48.16±0.79^b	137.5±0.88^b	48.18±0.77^b
FGM$_{150}$	41.6±1.23^a	58.74±0.53^a	22.5±0.63^a	41.4±1.34^a	120.3±2.33^a	54.95±0.58^a	187.8±1.87^a	54.59±0.31^a
LSD $_{0.05}$	3.46	1.71	1.80	3.66	4.95	2.24	3.89	1.93

Note: Means within a column followed by the same letter (a,b,c and d) are not significantly different ($P<0.05$). FGM: control, no green manure; FGM$_{50}$, FGM$_{100}$, and FGM$_{150}$: faba bean pod shells added as GM at rates of 50, 100, and 150 kg N ha^{-1}, respectively.

Table 9. Nitrogen use efficiency (% NUE$_{gm}$) of added green manure in the form of pea (PGM) or faba bean (FGM) pod shells in the different plant parts of sorghum.

Treatment	Panicles	Roots	Leaves	Whole Plant
	% NUE$_{gm}$			
	PGM			
PGM$_{50}$	8.97±0.18^a	4.61±0.37^a	30.27±0.49^a	45.38±0.12^a
PGM$_{100}$	8.79±0.13^a	3.60±0.11^b	28.83±0.75^a	42.15±0.63^b
PGM$_{150}$	6.65±0.18b	2.83±0.08^c	22.32±0.40^b	32.33±0.48^c
LSD $_{0.05}$	0.52	0.65	1.81	1.49
	FGM			
FGM$_{50}$	8.93±0.32^a	3.81±0.19^a	21.48±0.29^a	34.60±0.19^a
FGM$_{100}$	8.65±0.12^a	3.39±0.14^a	18.91±0.27^b	31.61±0.20^b
FGM$_{150}$	6.38±0.19^b	3.44±0.10^a	18.44±0.36^b	28.80±0.29^c
LSD $_{0.05}$	1.08	N.S	0.98	0.74

Note: For each green manure type, means within a column followed by the same letter (a,b,c and d) are not significantly different ($P<0.05$). PGM & FGM: control without green manure; PGM & FGM$_{50}$, PGM & FGM$_{100}$, and PGM & FGM$_{150}$: pod shells of pea (P) or faba bean (F) added as GM at rates of 50, 100, and 150 kg N ha^{-1}, respectively.

3.3. Nitrogen Use Efficiency (%NUE$_{gm}$) of Added Green Manure

Nitrogen use efficiency (%NUE$_{gm}$) of added green manure in the form of pea (PGM) or faba bean (FGM) pod shells in the different plant parts of sorghum are shown in Table **9**. Regardless of GM forms, % NUE$_{gm}$ values were high in leaves, followed by panicles and roots. In the whole plants, nitrogen use efficiency of added green manure decreased with increasing rates of applied GM. For pea pod shells (PGM) treatments, %NUE$_{gm}$ values were 45.4, 42.2, and 32.2% in PGM$_{50}$, PGM$_{100}$, and PGM$_{150}$, respectively. This result indicated that sorghum utilized approximately half of the N applied as pea shell pod wastes in PGM$_{50}$ and PGM$_{100}$ treatments, and third of the N applied in the PGM$_{150}$ treatment.

In regard to faba bean pod shells (PGM) treatments, the highest nitrogen recovery was in FGM$_{50.}$ There were slight but significant decreases in %Ndf$_{gm}$ as a result of increasing rates of applied GM. Values of %NUE$_{gm}$ in the whole plant were 35, 32, and 29%, in FGM$_{50}$, FGM$_{100}$, and FGM$_{150}$, respectively.

This indicates that sorghum utilized approximately a third of the N applied in the form of faba bean shell pod wastes.

4. DISCUSSION

4.1. Effects of Green Manuring with Pea and Faba Bean Pod Shell on Dry Matter Production and N Yield of Sorghum

Performance of sorghum plants grown on the soil amended with pea (PGM) or faba bean (FGM) pod shells wastes as green manure (GM) was examined using indirect ^{15}N isotope dilution. Sorghum plants responded positively and differently to the soil amendments with either GMs used. The results showed that dry weight and N yields of sorghum plants significantly increased by soil amendment with PGM or FGM as compared with un-manured treatments. The beneficial effects of leguminous green manures on the growth, yield, and N-uptake of the following crops, particularly, the sorghum plants, have been previously observed in different cropping systems [3, 21 - 24]. The increase in dry weight and that in N uptake caused by the application of pea (PGM) or faba bean (FGM) pod shells as green manures in sorghum plants may be attributed to the increase in available N released from GM. Moreover, other nutrient elements such as phosphorus could also promote plant growth. The beneficial effects following the green manure amendment on sorghum plants were affected by the mass of incorporated GM material in the soil. In comparison with the un-manured control treatment (N0), soil amendment with 3.5 t ha^{-1} of PGM (PGM_{100}) or with 6.5 t ha^{-1} of FGM (FGM_{150}) almost doubled the above-mentioned parameters in different plant parts of sorghum. Similarly, Fall *et al.* [17] reported that soil amendment with 4 to 6 t ha^{-1} of peanut shells significantly increased seedlings growth of threes leguminous trees. On the other hand, our study showed that growth and N uptake by sorghum plants were affected by the form of added GM. The enhancement in dry-matter production and N yield of sorghum was more pronounced in plants amended with pea than with faba bean pod shell residues. As indicated by Giller and Wilson [4], such differences may have resulted from variations in decomposition and immobilization rates between the two forms of plant material incorporated in the soil.

4.2. Effects of Green Manuring with Pea and Faba Bean Pod Shell on P uptake in Sorghum

In addition to the effect green manure of pea and faba bean pod shell on N uptake, the incorporation of GMs improved P content in sorghum plants. Bah, *et al.* [9] reported that improved availability of soil P due to the incorporation of plant materials has been attributed to direct P release from the decomposing materials and the action of other decomposition products on native soil P. Several researchers reported that the phosphorus in green manure can potentially be delivered to the soil in a form that is readily available to plants and soil microorganisms [25, 26]. Baddeley *et al.* [27] showed that the incorporation of a legume green manure can enhance biological phosphorus cycling in soil and improve its availability. In this study, the increase of phosphorus content in sorghum plants was relatively related to the mass of applied GM. In comparison with the control (N0), total phosphorus content in sorghum plants increased by 86, 140, and 148% for PGM and by 30, 92, and 101% for FGM, in N_{50}, N_{100}, and N_{150} treatments, respectively. Gao *et al.* [28] showed that the positive effect of alfalfa green manure on increasing yield of rice can be attributed to its good functions on increasing soil available P, promoting P uptake, and enhancing interactive effect of N and P. Such an organic amendment could increase some soil enzyme activities, such as dehydrogenase, urease, acid phosphatase, and β -glucosidase. The changes in soil enzyme activities affect the progress of nitrogen and phosphorus mineralization and release [28]. Pypers *et al.* [29] suggested that green manure with leguminous in crop rotation system increases the yield and growth of the maize plants, possibly for microbiological reasons, and the enhancement of P acquisition by plants resulted from improved soil P availability. On the other hand, phosphorus recovery following green manure crops may be derived from the decomposition and mineralization of incorporated plant material in the soil, from native P in the soil and from mineral P fertilizer. In this study, we did not estimate these values, only the total P content of the biomass. It is not possible to separate these P sources without using the ^{32}P isotope labeling technique [9]. However, it is evident that the incorporation of GMs improved P content in sorghum plants and may have contributed to yield increases. Based on the P-uptake under the two GM treatments (*i.e.* pea and faba bean pod shell), the phosphorus accumulation in total biomass of sorghum plants was 43, 29, and 20% higher in pea than faba bean, for N_{50}, N_{100}, and N_{150} treatments, respectively. Such increments may be partly attributed to differences in soil enzyme activities between the two types of GMs [28].

4.3. Effect of Green Manuring with Pea and Faba Bean Pod Shell on N Derived from Various Sources in Sorghum

Sorghum plants amended with GM (*i.e.* pea or faba bean pod shells), had lower atom %^{15}N excess values as compared to the un manured control treatment. This result indicated that a dilution effect had taken place and that some portions of sorghum N were derived from the incorporated GM in the soil [3, 10 - 12]. Regardless of GM used, estimated values of $\%Ndf_{gm}$ in sorghum plants, using the indirect ^{15}N isotope dilution method, ranged from 35% to 55%. This result indicated that the use of pod shells of leguminous as green manures provided substantial portions of N requirements for sorghum. Amounts of nitrogen derived from GM (Ndf_{gm}) in the whole plant of sorghum were 99, 183, and 211 mg N/pot for PGM and 75, 138, and 188 mg/N pot for FGM in N_{50}, N_{100}, and N_{150} treatments, respectively. As indicated by Rees *et al.* [30], the amounts of N taken up by plants were proportional to those applied in the form of legume residues. Moreover, based on amounts of N uptake from the two GM residues, (*i.e.* pea or faba bean pod shells), nitrogen accumulation in total biomass of sorghum plants were 31, 33, and 12% higher in pea than faba bean, for N_{50}, N_{100}, and N_{150} treatments, respectively. Such divergence may result from differences in the decomposition and mineralization rates of organic N between the two forms of plant material incorporated in the soil [4]. Consequently, our results showed a beneficial effect of using pea or faba bean pod shells as GMs to meet some of the N-requirement in sorghum plants.

With regard to soil (Ndfs) or fertilizer (Ndff) N uptake values (*i.e*, proportions and amounts), sorghum plants grown in a soil amended with pea pod shells (PGM) had significantly higher values in the different plant parts than those in the un-manured plants. (Table **7**). With the exception of roots, both Ndff and Ndfs values in shoots, panicles, and whole plant sorghum, amended with FGM were lower than those in the control, indicating that the enhancement of total N uptake of sorghum (Table **8**) mainly resulted from N released from FGM. However, amounts of soil or fertilizer N uptake in roots of the FGM treated plants were higher than those of the control, particularly in FGM_{100} and FGM_{150}, treatments. Moreover, a positive effect on sorghum root dry matter yield was also observed following the addition of both GMs (Tables **4** and **5**). The increase in the amount of soil N uptake by sorghum following the addition of plant residues as GMs, particularly PGM, was demonstrated in this study, a phenomenon highlighted previously by several authors [3, 30 - 32]. Jenkinson *et al.* [33] introduced the term "Added Nitrogen Interaction" or "priming effect" to describe any effect that the addition of N (*i.e.* organic N in the green manure) may have on the native soil N. Azam [34] reported that the extra nitrogen comes from soil organic matter as a result of the interaction of the added nitrogen. An increase in N availability from sources like soil organic matter could be attributed to a priming effect of the added nitrogen [34]. In other words, the added nitrogen interacts with the N already present in the soil, in a way to increase the availability of the later. Such an effect may result from an increase in root growth enabling the plants to explore a greater soil volume thus increasing the uptake of nutrients 'like soil N' by the green manured crops [33]. In this study, a positive effect on sorghum root dry matter yield was observed following the addition of both GMs. On the other hand, as suggested by Azam [31 - 34], there is a reason to believe that a priming effect may occur in soils because the endogenous soil microorganisms will react to the addition of energy-rich materials, and the increased microbial activity will involve mineralization process of the organic N in the GM. In view of our results, it can be concluded that the beneficial effects of incorporating pod shells in soil on sorghum nitrogen accumulation, may be attributed not only to the additional N released from GMs to the plants but also to their effects on the enhancement of soil N uptake which was more evident in PGM than FGM treatments [3, 12, 23].

4.4. Effect of Green Manuring with Pea and Faba Bean Pod Shells on N Recoveries (%NUE_{gm}) by Sorghum

Regardless of green manure used, nitrogen recoveries (%NUE_{gm}) in sorghum plants (uptake by plants) following the addition of pea or faba bean pod shells ranged from 29 to 45% indicating that both GM forms were used effectively. Release of N from pea GM which added to the soil 15 days before planting, seemed to be rapid with nearly half of N being utilized by the sorghum in PGM_{50} and PGM_{100}, and third of N in PGM_{150} treatments. For faba bean GM, around a quarter to third of its N content being used by the sorghum plants. Nearly, the same range of %NUE_{gm} values (20-52%) has been reported for sorghum manured with sesbania [3], Russian olive [12], or leucaena [23] leaves. However, the efficient use of green manure by sorghum plants was higher in treatment with pea than those with faba bean residues. It is well documented that organic nitrogen in the GM is released into the soil after incorporation through the process of mineralization by soil microorganisms [27]. The rate of this process is affected by many factors such as temperature, moisture, quantity, and quality (*i.e.* chemical composition) of the GM residue [4, 30, 35]. The ratio of carbon to nitrogen (C/N) is a useful guide for the decomposition and mineralization of the organic nitrogen in the added GM [4]. Abdelhamid *et al.* [36] reported that the lower the C/N the greater the mineralization rate. In this study, nitrogen recovery rates (uptake by sorghum) from pea pod shells were higher than those from faba bean probably because C/N of pea (15.2) was lower than that of faba bean (18). Moreover, Daimon [37] reported that not only the C/N ratio of the incorporated green manure involved in nitrogen release, but also other parameters such as lignin and polyphenols, ratio of lignin /N, ratio of polyphenols to total N, and ratio of (lignin + polyphenols) to total N are determining for GM quality regarding to N release after incorporation. Accordingly, GMs with a high ratio of these parameters are usually considered to compose more slowly than those of low ratio [37, 38]. In this study, all the above-mentioned parameters in PGM were lower than those in FGM (Table **2**). Such results may interpret the beneficial effects of the former over the latter GM regarding growth and N uptake by sorghum plants. Moreover, it is worth mentioning that the difference in polyphenols and polyphenols /N values between the two forms of GM were much higher than those of the other analyzed parameters (Table **2**). In other words, polyphenols and polyphenols /N mean values were 5 and 6 times higher in FGM than PGM, respectively. Whereas, other values were less high (*i.e.* 1.2, 1.2, 1.5, 1.4 times higher in FGM than PGM, for L, C/N, L+ph/N, and L/N, respectively), (Table **2**). This result may indicate the importance of polyphenols and polyphenols /N criteria in N released from GM. Our observation agrees well with the results of Fan *et al.* [39] who found that the impact of leaf litter polyphenols concentration and polyphenols /N ratio on N release rate was stronger than that of the C/N or lignin/N ratio.

While green manuring has been demonstrated to have beneficial effects on many aspects of the cropping systems, the most obvious direct economic benefit from the utilization of GM in agriculture is N fertilizer saving. It is well known that legume GM can replace a portion of the fertilizer N requirements for the subsequent crops. For example, Kurdali [11] reported that 18-54 kg N ha^{-1} of inorganic N fertilizer may be saved as a result of using dhaincha (*Sesbania aculeata* Pers.) plant residues as GM for sorghum growth. In this study, amounts of added nitrogen from GMs to sorghum were equivalent to 50, 100, and 150 kg N ha^{-1} (Table **3**). The use of PGM or FGM as green manures could substitute significant amounts of N fertilizer. For example, when PGM was used as a GM, recoveries of the added N by sorghum (%NUE_{gm}) were 45, 42, and 32% (Table **9**), for the above-mentioned treatments, respectively. Thus, equivalent amounts to 23, 42, and 48 kg N ha^{-1} of inorganic fertilizer may be saved using PGM as green manure for sorghum growth; whereas, 17, 32, and 43 kg N ha^{-1} of inorganic N fertilizer may be saved as a result of using

FGM.

Overall, this study demonstrated that the organic wastes of pea and faba bean pod shells applied to soil as GMs increased its fertility, like inorganic N fertilizer, and improved the growth of sorghum by enhancing nutrients uptake from soil and from organic sources. The use of these organic wastes as GMs is very useful to reduce chemical fertilizer application in cropping systems, maintain a sustainable N and P supply for crops and can be effectively used for soil rehabilitation and plant growth enhancement. In light of this study, the importance of using pea and faba bean pod shells wastes as green manures for plant growth enhancement is summarized in Fig. (**2**).

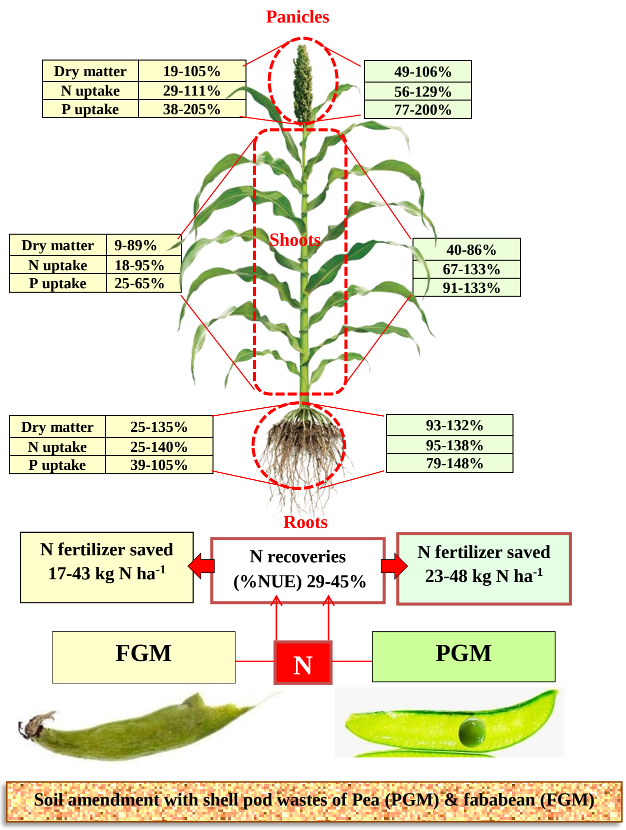

Fig. (2). Scheme representing the importance of using pea or faba bean pod shells 'after seed removals' as green manure in N fertilizer saving and in percent increments of dry matter, N and P uptake of different plant parts of sorghum, as compared with the un-manured control treatment. Data represents the lowest and the highest value of increments according to applied N in the form of GM. The lowest values belonged to N50 treatments that were higher in PGM than FGM. The highest values belonged either to N100 or to N150.

CONCLUSION

To the best of our knowledge, the present study is the first report on the use of organic wastes of pea and faba bean pod shells to be used as green manures for the growth of sorghum. Based on the data of all parameters in the research results, it can be concluded that soil amendment with these agricultural wastes has a significant influence on the productivity and nutrient uptake (*i.e.* N and P) in sorghum plants. Our results also indicated that PGM or FGM may substitute 17 to 48 kg N ha^{-1} of inorganic fertilizer. The use of such agricultural by-products as green manure is an additional way of handling the agricultural wastes in an organic farming system.

LIST OF ABBREVIATIONS

GM = Green Manure

PGM = Pea pod shells used as Green Manure

FGM = Faba bean pod shells used as Green Manure

Ndff = Nitrogen derived from fertilizer

Ndfs = Nitrogen derived from soil

Ndf_{gm} = Nitrogen derived from green manure

NUE_{gm} = Nitrogen Use Efficiency of added green manure

DM = Dry Matter

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

HUMAN AND ANIMAL RIGHTS

No animals/humans were used for studies that are the base of this research.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

Not applicable.

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CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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