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Response of *Aloe vera* to inorganic and organic fertilization in relation to leaf biomass yield and post harvest fertility of soil

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Abstract

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The versatile properties of *Aloe vera* for various purposes have been well documented. Inorganic fertilizer along with organic manure is essential for proper plant growth maintaining soil health. The research was aimed to find out the integrated effects of inorganic fertilizer (IF) and poultry manure (PM) on the growth and leaf biomass yield of *A. vera* and post-harvest soil fertility along with the economics of *A. vera* cultivation. Different combinations of IF and PM exerted significant influence on the growth, yield attributes and leaf biomass yield of *A. vera*. The highest fresh leaf weight (4864 g plant^{-1}), fresh gel weight (2956 g plant^{-1}) and dry leaf weight (420.70 g plant^{-1}) at harvest were obtained from the plant treated with 25% IF and 75% PM whereas the tallest plant (57.14 cm) and highest number of leaves plant^{-1} (18.33) were identified from the pot treated with $IF_{100}PM_0$. About 153% yield increase over control was noticed from $IF_{25}PM_{75}$ which was statistically identical with the yield increase of the treatment $IF_{100}PM_0$. Correlation studies revealed that fresh gel weight was significantly and positively correlated with plant height, number of leaves, leaf area and fresh leaf weight. The pH, organic matter, total N, available P, exchangeable K, Ca, Mg and available S, Zn, B contents of post-harvest soil were significantly increased with the increased levels of PM. Based on BCR (Benefit Cost Ratio) value (1.72), $IF_{25}PM_{75}$ was the best profitable treatment. Farmers belonging to the agro-climatic conditions of the study area may be advised to cultivate *A. vera* in acid soil applying 75% poultry manure along with 25% inorganic fertilizer for getting maximum leaf biomass yield and benefit maintaining soil fertility and productivity.

Keywords: inorganic fertilizer; poultry manure; *Aloe vera;* leaf yield; soil fertility; BCR

Introduction

Plants, herbs, and ethno botanicals have been used throughout the world for health advancement and treatment of illness since the beginning of mankind. *Aloe vera,* a member of Liliaceae family, is considered as an important medicinal plant cultivated in many countries of the world (Hasanuzzaman et al., 2008). It sometimes referred as a "miraculous" plant. It is well-known for the treatment of different diseases mainly skin problem as well as for many disorders like constipation, stomach disease, hair loss, kidney disease and others (Park and Lee, 2006). Products containing *A. vera* are used for the treatment of minor cuts and burns and to heal wounds (Barandozi et al., 2011). *A. vera* cultivation has acquired great commercial importance for different purposes such as medicinal products and cosmetics processing. Bangladesh at present spends about Tk. 5000 million on the import of herbs and herbal extracts to make medicine. So, the market opportunity of *A. vera* is estimated to be approximately 90,000 USD (Dixie et al., 2003). Incorporation of *A. vera* into agricultural production systems depends upon detailed information regarding the plant, its agronomic potential and nutritional requirement (Ramesh et al., 2007). Being a succulent plant *A. vera* is more responsive to nutrient. But the farmers are not using any recommended farming practices for *A. vera* cultivation which resulted poor yield. So, the fertility management of *A. vera* may be one of the strategies for increasing the yield (Saha et al., 2005).

Nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) are the key nutrients which manipulate plant growth by influencing all vital processes in plants *viz.,* protein, energy metabolism, the synthesis of nucleic acids and membranes, photosynthesis, respiration, nitrogen fixation and enzyme regulation (Raghothama, 1999). Consequently, getting more crop production, N, P, K and S application is essential in the form of chemical fertilizer (Ali et al., 2000). The requirement of N, P, K and S for the growth and biomass yield of *A. vera* is unknown in Bangladesh. However, the excess doses of chemical nutrient as well as improper sources can show negative effect on leaf yield and quality. Along with the chemical fertilizers, organic manures can be mixed to the soil to control nutrient deficiency, increase organic matter content, water holding capacity of the soil to stimulate the activity of beneficial microorganisms that make the nutrient elements readily available to the plants. Organic manure like decomposed cowdung, poultry manure, green manure, farm yard manure, sewage slurry, biogas slurry and vermicompost etc. can be applied to improve the soil physical, chemical and biological conditions along with an increase in the amount of nutrients. As poultry industry has been increasing dramatically over last few decades in Bangladesh, poultry manure (PM) has long been recognized as perhaps the most desirable animal manures because of its high nutrient content.

Considering its availability in our country, addition of PM along with inorganic fertilizers to the *A. vera* could be a very good option for maintaining soil fertility and productivity. So, it is necessary to find out a suitable recommendation for inorganic fertilizer and PM in *A. vera* farming. A few sporadic trials on the growth and leaf yield of *A. vera* have been conducted at pot conditions (Hasanuzzaman et al., 2008). Unfortunately, no detailed study has yet been published on organic and inorganic management practices, post-harvest soil fertility and economics of *A. vera* cultivation. In view of the above facts, cultivation of *A. vera* gradually coming into focus in Bangladesh agriculture due to its enormous prospect both at home and abroad. It is now imperative to develop an appropriate dose of IF and PM for the cultivation of *A. vera* to boost up its production in Bangladesh.

Materials and Methods

The experiment was laid out at the net house of the Department of Agricultural Chemistry, Bangladesh Agricultural University (BAU), Mymensingh during of 2017-18 following completely randomized design (CRD) with three replications. Acid soil was used for this experiment, physicochemical properties of which were described by Chowdhury et al. (2018). Six combinations of IF and PM *viz.,* IF_0PM_0 (control), $IF_{100}PM_0$ (100% of IF only), $IF_{75}PM25$ (75% IF plus 25% PM), $IF_{50}PM_{50}$ (50% IF plus 50% PM), IF_2PM_{75} (25% IF plus 75% PM), IF_0PM_{100} (100% of PM only) were used as treatment. Inorganic fertilizer (IF) consisting of urea, TSP, MoP and gypsum @150, 80, 120, 30 kg ha^{-1}, respectively (Biswas, 2010) and PM @ 5 t ha^{-1} was applied. One-third amount of urea and full doses of PM and other fertilizers were applied during pot preparation and the rest two installments of urea were applied at 60 and 120 days after planting (DAP). The pot was filled by mixed soil leaving 3 cm from the top and labeled with permanent marker. Distilled water was added in each pot, covered with polyethylene and kept for one week before transplanting.

Total nutrient concentrations of used PM were 16.86, 2.20, 1.72, 0.42, 0.27, 0.21 and 0.016% organic C, total N, P, K, S, Ca and Mg, respectively. Eighteen months old *A. vera* seedlings were collected from the local farm of Shomvogonj, Mymensingh and planted in each pot during 2^{nd} week of October, 2017 and was harvested at 180 DAP. Irrigation, soil loosening and weeding were scheduled as and when necessary. Leaves were collected carefully and cleaned with tap water followed by distilled water to remove soil and other foreign materials. Physical and chemical properties of post-harvest soil were analyzed following standard procedure (Black, 1965; Page et al., 1982) in the laboratories of the departments of Agricultural Chemistry, Professor Muhammed Hussain central laboratory (PMHCL), BAU, Mymensingh and SRDI regional laboratory, Dhaka. Analysis of variance (ANOVA) was done following the principal of F-statistics and the mean values were separated by Duncan's Multiple Range Test (Gomez and Gomez, 1984). Different economic parameters were calculated as follows:

BCR = Gross return ha^{-1}/ Total cost of production ha^{-1}

Total yield = total leaf yield (ha^{-1}) + total seedling yield (ha^{-1})

Total leaf yield (ha^{-1}) = Total no. of plant ha^{-1} × average no. of leaves $plant^{-1}$

Total seedling yield (ha^{-1}) = Total no. of plant ha^{-1} × average no. of seedlings $plant^{-1}$

Gross income = {Leaf yield ha^{-1}×Value rate (Tk. $leaf^{-1}$)} + {Seedling yield ha^{-1}
× Value rate (Tk. $seedling^{-1}$)}

Net profit = Gross income – Total cost of production

Results and Discussion

Effects of IF and PM on plant height of A. vera

The application of different levels of IF and PM had a significant effect on the plant height of *A. vera* (Table 1). Plant height was significantly increased during growth period and reached their maximum values at harvest. The tallest plant (57.14 cm) was identified from the pot treated with $IF_{100}PM_0$ which was identical with $IF_{75}PM_{25}$ treated plants. The shortest plant (35.22 cm) was noted from control (IF_0PM_0) treatment. Plant height was increased by 21.92 cm from $IF_{100}PM_0$ treatments over control. The plants treated with higher doses of IF had higher plant height than PM treated plants. PM along with IF ensured the availability of other essential nutrients for plant and gave taller plant than control. The result was corroborated with the reports of Farooq et al. (2015) that showed increased plant height with increasing application of organic fertilizers. It is also in agreement with the finding of Jayathilake et al. (2002) who reported highest plant height through the application of organic manures plus 50% N and 100% PK in onion. Kumar et al. (2013) noticed that combined application of chemical fertilizer and poultry manure increased the plant height of stevia. In a field study, Khan et al. (2012) reported that availability of nutrients increased the biomass of plants. Similar results were also reported by Kobayoshi et al. (1989) applying FYM plus fertilizer N in rice.

Effects of IF and PM on leaf number of A. vera

The data pertaining to the leaf number of *A. vera* as significantly influenced by the integrated effects of IF and PM are presented in Table 1. The highest number of leaves plant^{-1} was counted from the plant treated with $IF_{100}PM_0$ which was statistically identical with $IF_{25}PM_{75}$ and $IF_{75}PM_{25}$. In contrast, the lowest number of leaves was observed in the plant neither receiving PM nor IF. The growth of the plants of the control treatment tended to be stunted and produced fewer leaves than fertilized pots. Except control, among other treatment combinations, the lowest number of leaves was counted from the plant fertilized with IF_0PM_{100} and $IF_{50}PM_{50}$ which was significantly different from other treatments.

From this study it was observed that the application of $IF_{100}PM_0$, $IF_{75}PM_{25}$ and $IF_{25}PM_{75}$ increased leaf number by 72%, 69% and 50% over control, respectively. Mean leaf number was increased by 49% over control. The production of greater number of leaves could be due to higher metabolic activity because of the higher availability of macro and micro nutrients from PM and NPKS resulting in higher production of carbohydrates and phytohormones which were manifested in the form of enhanced growth as explained by Govindan and Purushottam (1984). Enhanced leaf parameters with increased levels of fertilizers were also reported previously (Khanom et al*.,* 2008). This is also identical with Zaman et al. (2017), where the increased leaf number was achieved in stevia due to the combined application of higher levels of PM and integrated IF.

Effects of IF and PM on leaf area of A. vera

Leaf area is used to predict primary photosynthate (compound) production, evapotranspiration and as a reference tool for crop growth which plays an essential role in theoretical production ecology (Wilhelm et al*.,* 2000). The application of IF and PM in different combinations had no significant effect on the mean leaf area of *A. vera* (Table 1). The highest mean leaf area plant^{-1} (334 cm^2) was measured from the plant fertilized with IF_0PM_{100} which was identical with all other combinations of IF and PM along with control. The lowest mean leaf area plant^{-1} (284 cm^2) was noticed in the plant grown in control. Mean leaf area was increased by

Table 1. Integrated effects of IF and PM on plant height, number of leaves, mean leaf area and leaf dry weight of *A. vera* at harvest

IF and PM levels	Plant height, cm	Number of leaves plant^{-1}	Mean leaf area plant^{-1}, cm^2	Leaf dry weight, g plant^{-1}
IF_0PM_0	35.22±2.73d	10.67±1.5c	284±46	166.16±15.0d
$IF_{100}PM_0$	57.14±2.51a	18.33±1.5a	292±35	414.07±39.18a
$IF_{75}PM_{25}$	51.14±5.89ab	16.0±2.0a	299±33	339.27±28.43b
$IF_{50}PM_{50}$	45.62±3.02bc	14.33±1.5b	297±30	318.04±29.33bc
$IF_{25}PM_{75}$	48.54±7.35bc	18.0±2.6a	332±37	420.70±24.87a
IF_0PM_{100}	41.42±3.88c	12.67±2.1b	334±18	273.97±32.43c
CV%	9.04	12.86	11.19	9.05
$LSD_{0.05}$	7.48**	3.44*	NS	51.86**

IF = Inorganic fertilizers; PM = Poultry manure; NS = not significant. Means within the same column followed by the different letter(s) were significantly different according to DMRT **P < 0.01; *P < 0.05, Values are mean ± SD; LSD = Least significant difference; CV = Coefficient of variance

50 cm^2 across the treatments over control. The result was different from the results reported by Agbede & Adekiya (2012) and Zaman et al. (2017). On the other hand, Jamir et al. (2017) reported that vermicompost in combination with IF increased leaf area of pepper more significantly than PM.

Effects of IF and PM on fresh leaf weight of A. vera

Different combinations of IF and PM had significantly influenced the leaf fresh weight of *A. vera* plant^{-1} at harvest (Figure 1). Results revealed that leaf fresh weight progressively increased with the different combinations of IF and PM up to $IF_{25}PM_{75}$. The highest leaf fresh weight plant^{-1} (4864 g) at harvest was measured from the plant receiving $IF_{25}PM_{75}$ followed by $IF_{100}PM_0$ (4787g), and both of them were identical. Plants treated with $IF_{75}PM_{25}$ and $IF_{50}PM_{50}$ produced 3922 and 3677 g plant^{-1}, respectively. The lowest values were obtained from the control treatment (1921 g plant^{-1}). Leaf fresh weight was increased by 1697 g plant^{-1} over sole application of PM across the treatments. Either sole application of IF or combined application of IF and PM play important roles in increasing the leaf fresh and dry weight of the crop. Hasanuzzaman et al. (2008) showed that organic fertilizers increased leaf fresh weight of *A. vera* and it is in line with the present results. Goussous & Mohammad (2009) reported an increase of leaves fresh weight of *Allium cepa* due to N and P fertilizers.

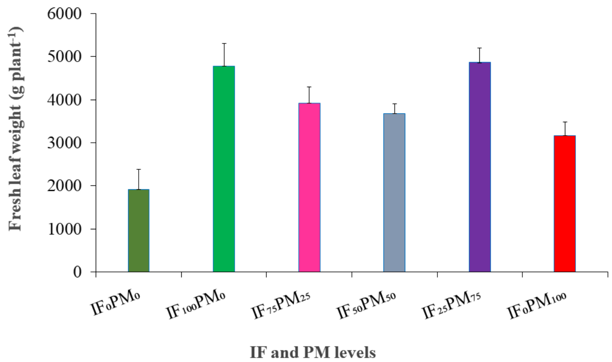

Fig. 1. Integrated effects of IF and PM on the fresh leaf weight of *A. vera*

In this context, Prabha et al. (2007) reported that the plant weight and growth were increased due to the absorption of mineral nutrients such as N and plant growth regulators. The investigations of Atiyeh et al. (2002) had shown that suitable effects of PM occurred due to physical, chemical, biological and microbial characteristics of changing conditions. Also, other causes included pH regulation and a significant increase in water storage capacity of the substrate. On the other hand, the increase in plant height caused the leaf weight to increase. It is effective in increasing the amount of gel. According to Muscolo et al. (1999) it can stimulate hormone production such as auxin. Also, excessive microbial activity increased the concentration of nitrogen in plants (Arancon et al., 2004).

Effects of IF and PM on fresh gel weight of A. vera

Different combinations of IF and PM significantly influenced the fresh gel weight of *A. vera* plant^{-1} at harvest (Figure 2). Comparison of data indicates that an increase in PM causes the gel weight to increase as well, so that the maximum gel was showed in $IF_{25}PM_{75}$ and declined with sole application of PM. The highest gel weight plant^{-1} (2956 g) at harvest was measured from the plant receiving $IF_{25}PM_{75}$ which was significantly higher than other treatments except sole application of IF (2854 g plant^{-1}). Statistically second highest gel weight (2117 g plant^{-1}) was found from the plants treated with $IF_{75}PM_{25}$ which was identical with gel weight of the plants treated with combined 50% of IF and 50% of PM. The control treatment had the lowest amount of gel (941 g plant^{-1}). The highest fresh gel weight was increased by 214.13% over control across the treatments.

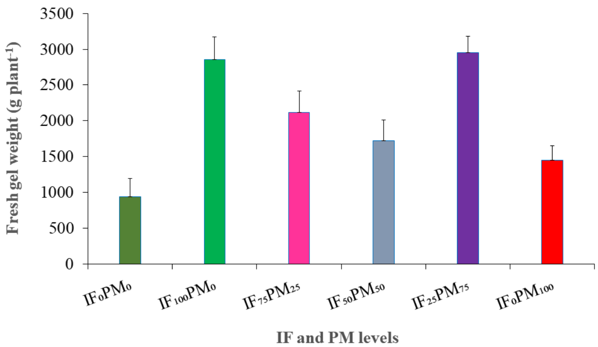

Fig. 2. Integrated effects of IF and PM on the fresh gel weight of *A. vera*

The experiments by Saha et al. (2005) and Nematian et al. (2010) confirmed that the nutrient minerals, such as N and K, increase leaf growth and lead to a substantial amount of gel in *A. vera*. From inorganic fertilizers plants got nutrients immediately than PM at initial stage but gradually it decreased as the nutrient lost from the soil by various means. On the other hand, application of NPKS and PM together increase the availability of nutrients throughout the whole growing period of the plant. The supply of nutrients, such as N, P, K and S, played a significant role in growth and primary metabolism performance. As the availability of food for the plant increased, the amount of photosynthesis increased as well as the amount of carbon. It causes the increasing amount of carbon and the increase in carbon can be used in the synthesis of primary and secondary compounds which resulted higher gel weight (Bryant et al., 1983). Zarandi et al. (2011) reported that the fresh and dry weight shoots in *Ocimum basilicum* plant in all organic treatments was significantly higher than the control and chemical treatments.

Effects of IF and PM on dry leaf weight of A. vera

The dry weight of *A. vera* leaves plant^{-1} at harvest varied significantly due the application of different levels of IF and PM (Table 1). Results revealed that dry weight progressively increased with increasing levels of IF and PM application. The highest dry weight plant^{-1} (420.70 g) at harvest was measured from the plant receiving $IF_{25}PM_{75}$ which was significantly different from other levels of IF and PM except $IF_{100}PM_{0}$ (414.07 g plant^{-1}). The lowest value was obtained from the control. Better performance of crops with NPKS fertilizer combined with PM in all the growth characters observed infers that the plant positively responded to NPKS fertilizer and PM which agreed with earlier finding of Olatunji and Oboh (2012). The finding in this experiment also corroborated the findings of Li and Mahler (1995) who obtained better vegetative development in wheat, most especially when soil was amended with inorganic and organic materials of low C:N ratio. The better performance of pot with PM + NPK fertilizer corroborated the result of Ogundare (2011) and Asadu & Unagwu (2012). The results of present study are also in agreement with the findings of Parvez et al. (2008). Poultry manure also demonstrated superior effect in producing straw yield of rice as compared to cowdung and IF. The leaf yield was 153% higher in respect of combined application of 25% IF and 75% PM than that of control (Figure 3). Leaf dry weight was increased by 65 to 153% over control across the treatments.

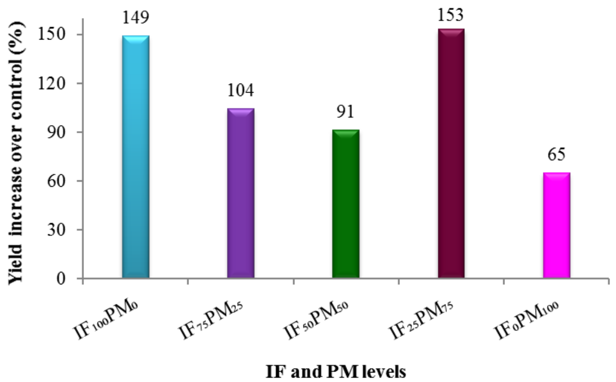

Fig. 3. Integrated effects of IF and PM on yield increase over control of *A. vera*

Correlation among different physical parameters of A. vera

Statistical relationship of plant height, leaf number and fresh leaf weight with fresh gel weight has been found out. The correlation and regression lines of the parameters have been shown in Figure 4. The results showed that the concerned physical parameters were significantly and positively correlated with fresh gel weight where correlation coefficients (r) were 0.763*, 0.809* and 0.940**, respectively. The relationships were more evident from the regression lines (y = 73.63x – 1418, y = 190.9x – 857.1 and y = 0.679x – 521.9, respectively) where increase of concerned parameters increased fresh gel weight significantly. Ramabai et al. (1992) observed significant and positive association between grain yield plant^{-1} and number of productive tillers hill^{-1}, plant height, panicle length and number of grains panicle^{-1} both at genotypes and phenotypic levels.

Effects of IF and PM on post-harvest soil fertility

Application of IF and PM significantly influenced the post-harvest properties of the soil (Tables 2 and 3). The data reveal that the pH of the soil ranged from 5.1 to 6.3 when PM was applied with or without IF. The acidity of the soil was reduced to some extent and favors the growth and yield

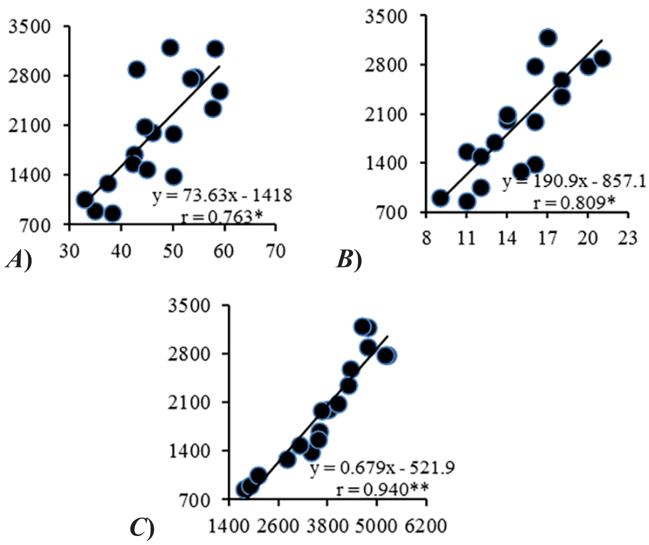

Fig. 4. Relationships of plant height (*A*), number of leaves (*B*) and FLW (*C*) with FGW of *A. vera* as influenced by different integrated levels of IF and PM. FLW = Fresh leaf weight, FGW = Fresh gel weight (n = 18)

Table 2. Integrated effects of IF and PM on the fertility of post-harvest soils

IF and PM levels	pH	Organic matter, %	Total N, µg g^{-1}	Available P, µg g^{-1}	Exch. K, C mol kg^{-1}
IF_0PM_0	5.1±0.2d	1.56±0.3d	0.09±0.0e	3.04±0.2f	0.19±0.05c
$IF_{100}PM_0$	5.3±0.1cd	1.92±0.1c	0.18±0.0d	4.64±0.1e	0.22±0.03c
$IF_{75}PM_{25}$	5.6±0.4c	2.24±0.1b	0.25±0.0c	6.21±0.3d	0.26±0.03bc
$IF_{50}PM_{50}$	5.8±0.4bc	2.36±0.1ab	0.29±0.0bc	7.04±0.1c	0.3±0.05ab
$IF_{25}PM_{75}$	6.1±0.2ab	2.42±0.1ab	0.31±0.0b	8.68±0.2b	0.32±0.05ab
IF_0PM_{100}	6.3±0.3a	2.5±0.2a	0.37±0.0a	9.94±0.2a	0.38±0.06a
CV%	4.58	7.32	8.63	2.57	16.13
$LSD_{0.05}$	0.46*	0.28*	0.04**	0.30**	0.08*

Exch. = Exchangeable; IF = Inorganic fertilizers; PM = Poultry manure; NS = not significant; LSD = Least significant difference; CV = Coefficient of variance. Means within the same column followed by different letter(s) were significantly different according to DMRT (**P < 0.01; *P < 0.05), Values are mean ± SD

of *A. vera*. Wang et al. (2013) are of the same opinion that any organic material if added to the soil that will reduce soil acidity. They reported that addition of the plant residues increased soil pH by 0.2 – 1.2 U. This might be due to the fact that when organic residues (plant or animal) were added to the soil, they released organic anions which neutralized the hydrogen ion of the acid soil.

Organic matter content ranged from 1.56 to 2.50%. This increasing OM content of the soil might be due to the additions of PM. The contents of total N, available P, exchangeable K, Ca, Mg, available S, Zn and B were significantly increased with the increased levels of PM. The highest values of all the parameters were obtained from sole application of PM and the lowest from the initial soil (IF_0PM_0) as the nutrients released rapidly and consistently from this manure over the growth period of *A. vera*. However, changes due to IF and PM was not significant because other factors such as the soil texture, pH, and the soil buffering capacity (McCauley et al., 2009) might had played in enabling the study soil to resist to changes brought about by IF and PM applications.

The other possible mechanism through which N, P, K and S were higher in only PM treated soils could be the steady supply of N, P, K and S to plants from the fertilizer. In these conditions, plants did not depend much on soil N, P, K and S while soil N, P, K and S from other treatments were being depleted by growing plants. Poultry manure is an organic fertilizer rich in all essential plant nutrients (Gupta, 2003). PM often contains much higher nutrients than traditional organic fertilizers i.e. cowdung, sewage sludge (Alam et al., 2007). Guerrero et al. (2001) found that organic matter addition is a suitable technique for accelerating the natural recovery process of burned soils.

Economics of A. vera cultivation

The economic analysis gives an overview on the crop production cost components. Input costs for land preparation, seed, fertilizer, irrigation and man power required for all the operations from sowing to harvesting were calculated for cost per hectare considering the requirements pot^{-1}. For the economic analysis, the prevailing market price for inputs during planting time and outputs (*A. vera* in particular) during harvesting time was considered.

The highest total cost of production (tk. 506 013) was obtained from the treatment combination of IF_0PM_{100} and the

Table 3. Integrated effects of IF and PM on the fertility of post-harvest soils

IF and PM levels	Available S, µg g^{-1}	Exch. Ca, Cmol kg^{-1}	Exch. Mg, Cmol kg^{-1}	Available Zn, µg g^{-1}	Available B, µg g^{-1}
IF_0PM_0	11.86±0.3d	0.25±0.0e	0.6±0.2d	1.31±0.2d	0.33±0.2a
$IF_{100}PM_0$	16.45±0.4c	2.16±0.3d	0.88±0.2cd	1.75±0.2c	0.65±0.2ab
$IF_{75}PM_{25}$	17.35±0.3c	2.53±0.1c	0.97±0.1bc	1.94±0.2bc	0.68±0.2ab
$IF_{50}PM_{50}$	18.11±1.5bc	2.75±0.1c	1.05±0.1bc	2.08±0.1b	0.74±0.2b
$IF_{25}PM_{75}$	19.35±0.6b	3.52±0.1b	1.1±0.0ab	2.19±0.0ab	0.88±0.2b
IF_0PM_{100}	22.1±1.6a	4.83±0.3a	1.31±0.1a	2.36±0.1a	0.98±0.2c
CV%	5.48	6.68	13.05	7.2	0.2584
$LSD_{0.05}$	1.71**	0.32**	0.23*	0.25**	20.55*

Exch. = Exchangeable; IF = Inorganic fertilizers; PM = Poultry manure; NS = not significant;
LSD = Least significant difference; CV= Coefficient of variance. Means within the same column followed by different letter(s) were significantly different according to DMRT (**P < 0.01; *P < 0.05), Values are mean ± SD

Table 4. Cost and profit of *A. vera* cultivation as influenced by IF and PM

Product	Yield		Value rate		Gross income (tk.)	Total cost of production (tk.)	Net profit (tk.)	Benefit cost ratio
	No. of leaf ha^{-1}	No. of seedling ha^{-1}	tk. $leaf^{-1}$	tk. $seedling^{-1}$				
IF_0PM_0	43 891	4 588	10	20	530 670	477 763	52 907	1.11
$IF_{100}PM_0$	59 447	10 145	10	20	797 370	485 006	312 364	1.64
$IF_{75}PM_{25}$	56 322	9 046	10	20	744 140	490 258	253 882	1.52
$IF_{50}PM_{50}$	52 979	7 761	10	20	685 010	495 510	189 500	1.38
$IF_{25}PM_{75}$	63 408	11 470	10	20	863 480	500 761	362 719	1.72
IF_0PM_{100}	49 560	5 912	10	20	613 840	506 013	107 827	1.21

1 tk = 0.011 Euro

second highest (tk. 500 761) was obtained from $IF_{25}PM_{75}$. The lowest total input cost (tk. 477 763) was calculated from the treatment combination of IF_0PM_0. Combination of IF and PM showed different gross income under the trial. The highest gross income (tk. 863 480) was obtained from the treatment combination of $IF_{25}PM_{75}$ and the second highest gross income (tk. 797 370) was obtained from $IF_{100}PM_0$. The lowest gross income (tk. 530 670) was calculated from the treatment combination of IF_0PM_0 (Table 4). In case of net profit, different treatment combinations showed different types of net profit. The highest net profit (tk. 362 719) was obtained from the treatment combination of $IF_{25}PM_{75}$ and the second highest net profit (tk. 312 364) was obtained from the treatment combination of $IF_{100}PM_0$. In contrast, the lowest net profit (tk. 52 907) was obtained from the treatment combination IF_0PM_0 (Table 4).

Benefit cost ratio (BCR)

The benefit cost ratio measures the efficiency of investment in *A. vera* cultivation. Average return to each taka spent on production is an important criterion for measuring profitability in growing a crop. In the combination of different IF and PM, the highest BCR (1.72) was obtained from the treatment combination of $IF_{25}PM_{75}$ and the second highest BCR (1.64) was estimated from the treatment combination of $IF_{100}PM_0$. The lowest BCR (1.11) was obtained from the treatment combination of IF_0PM_0 (Table 4). According to Kelly and Murekezi (2000), treatments with BCR values lower than 2 are not worthy in farmers' perspectives. The farmer cannot shift from one crop cultivation to another unless benefits are sure.

According to CIMMYT (1988), marginal benefits need to be 1.18 times the marginal costs to be attractive to farmers. All fertilizer treatments did not meet this requirement. This is consistent with the result reported by Celestin (2013) in Rowanda that application of FYM and ½ DAP + ½ FYM were more profitable in maize but not in common bean and soybean. From economic point of view, it is apparent from the above results that the treatment combination of $IF_{25}PM_{75}$ and sole application of inorganic fertilizer was quite similar but considering other factors the treatment combination of $IF_{25}PM_{75}$ was more profitable among the concerned treatments.

Conclusions

The application of IF and PM in different combinations had a significant effect on the growth, yield and yield attributes of *A. vera*. Measured growth and yield parameters performances increased with increase in application rate of PM along with IF. The highest values of different growth and yield parameters of *A. vera* was obtained from the pot treated with $IF_{25}PM_{75}$ at harvest which was identical with the values obtained from the pot treated with $IF_{100}PM_0$. The use of poultry manure along with inorganic fertilizer is therefore recommended to farmers because these are readily available to almost all the farmers in Bangladesh. Application of combined IF and PM significantly affected the post harvest properties of acid soil by the improvement of nutrients availability to the plants. Per hectare yield and gross returns of *A. vera* were also higher when $IF_{25}PM_{75}$ was used than the other treatments. Considering the socio-economic conditions farmers may be advised to cultivate *A. vera* in acid soils applying 75% PM (5 t ha^{-1}) along with 25% inorganic fertilizer (N, P, K and S @ 150, 120, 75 and 30 kg ha^{-1}, respectively) under the agro-climatic conditions of the experimental area. Information of this research will explore a new field for the root level farmers to policy makers by which the cultivation of *Aloe vera* can be popularized throughout the country.

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References

Agbede, T. M. & Adekiya, A. O. (2012). Effect of poultry manure on soil fertility, growth and yield of white yam and yellow yam. Univ. Khartoum *J. Agril. Sci., 20(3),* 286-303.

Alam, A. K. M. M. (2007). Recycling of nutrients under jute based cropping pattern, Ph.D Thesis, Soil Water and Environment Department, University of Dhaka, Bangladesh. 150.

Ali, A., Choudhry, M. A., Malik, M. A., Ahmad, R. & Saifullah (2000). Effect of various doses of nitrogen on the growth and yield of two wheat cultivar. *Pakistan J. Biol. Sci., 3,* 1004-1005.

Arancon, N. Q., Edwards, C. A., Atiyeh, R. M. & Metzger, J. D. (2004). Effects of vermicomposts produced from food waste on greenhouse peppers. *Biores. Technol., 93,* 139-144.

Asadu, L. A. & Unagwu, B. O. (2012). Effect of combined poultry manure, and inorganic fertilizer on maize performance in an ultisol of Southeastern Nigeria. *Nigerian J. Soil Sci., 22(2),* 79-87.

Atiyeh, R. M., Arancon, N., Edwards, C. A. & Metzger, J. D. (2002). The influence of earthworm processed pig from vegetative meristems. *J. Plant Biotech., 20(1),* 71-74.

Barandozi, F. N., Enferadi, S. T. & Naghavi, M. R. (2011). Effects of fertilizer on morphological traits in *Aloe vera. J. Med. Plants Res., 5(18),* 4537-4541.

Biswas, B. C. (2010). Cultivation of medicinal plant. Ferti. *Marketing News, 41(3),* 1-4.

Bryant, J. P., Chapin, F. S. & Klein, D. R. (1983). Carbon/nutrient balance of boreal plants in relation to vertebrate herbivory. *Oikos.*, *40,* 357-368.

Celestin, N. P. (2009). Effects of inorganic and organic fertilizers on nutrient uptake, soil chemical properties and crop performance in maize based cropping systems in eastern province of Rwanda. Department of Environmental Sciences, Kenyatta University, Kenya.

Chowdhury, T., Rahman, M. A., Nahar, K., Chowdhury, M. A. H. & Khan, M. S. I. (2018). Growth and yield performance of *Aloe vera* grown in different soil types of Bangladesh. *J. Bangladesh Agric. Univ., 16(3),* 448-456.

CIMMYT (1988). From agronomic data to farmer recommendations: An economic training manual. Completely revised edition. Mexico D. F.: CIMMYT.

Dixie, G., Hussain, M. J. & Imam, S. A. (2003). Medicinal plant marketing in Bangladesh. A publication by Interco Operation and South Asia Enterprise Development Facility. 8-22.

Farooq, M., Shah, A. H., Malik, A. A., Ali, N., Khan, U., Majid, A. & Ahmad, H. (2015). Nutrient management for improving onion productivity. *American-Eurasian J. Agric. Environ. Sci., 15(2),* 220-225.

Gomez, K. A. & Gomez, A. A. (1984). Statistical procedure for agricultural research. 2nd ed. International Rice Research Institute, Los Banos, Philippines, 207-215.

Goussous, S. J. & Mohammad, M. J. (2009). Comparative effect of two arbuscular mycorrhizae and N and P fertilizers on growth and nutrient uptake of onions. *Int. J. Agr. Bio., 11(4),* 463-467.

Govindan, M. & Purushottam, D. (1984). Production of phytohormones by the nitrogen fixing bacteria Azospirillum. *Agric. Res. J., 22(2),* 133-138.

Guerrero, C., Gomez, I., Moral, R., Mataix-Solera, J., Mataix-Beneyto, J. & Hernandez, T. (2001). Reclamation of a burned forest soil with municipal waste compost: macronutrient dynamics and improved vegetation cover recovery. *Bioresour. Technol., 73(3),* 221-227.

Gupta, P. (2003). Vermicomposting for sustainable agriculture. Agrobios, India, 188.

Hasanuzzaman, M., Ahamed, K. U., Khalequzzaman, K. M., Shamsuzzaman, A. M. M. & Nahar, K. (2008). Plant characteristics, growth and leaf yield of *Aloe vera* L. as affected by organic manure in pot culture. *Aust. J. Crop Sci., 2(3),* 158-163.

Jamir, T., Rajwade, V. B., Prasad, V. M. & Lyngdoh, C. (2017). Effect of organic manures and chemical fertilizers on growth and yield of sweet pepper (*Capsicum annuum* L.) hybrid Indam Bharath in shade net condition. *Int. J. Curr. Microbiol. App. Sci., 6(8),* 1010-1019.

Jayathilake, P. K. S., Reddy, I. P., Shrihari, D., Neeraja, G. & Reddy, R. (2002). Effect of nutrient management on growth, yield and yield attributes of rabi onion (*Allium cepa*). *Vegetable Sci., 29(2),* 184-185.

Kelly, V. & Murekezi, A. (2000). Fertilizer response and profitability in Rwanda -A synthesis offindings from MINAGRI studies conducted by the food security research project (FSRP) and the FAO soil fertility initiative. Kigali, Rwanda: Ministry of Agriculture, Animal Resources, and Forestry.

Khan, M. A., Marwat, K. B., Amin, A., Nawaz, A. & Khan, H. (2012). Soil solarization: an organic weed management approach in cauliflower. *Commun. Soil Sci. Plant Anal., 43(13),* 1847-1860.

Khanom, S., Chowdhury, M. A. H., Islam, M. T. & Saha, B. K. (2008). Influence of organic and inorganic fertilizers on mineral nutrition of Stevia in different types of soil. *J. Bangladesh Agric. Univ.*, *6,* 27-32.

Kobayshi, Y., Abe, S. & Matsumoto, K. (1989). Growth and yield of paddy rice under natural cultivation. Rep. *Tohoku Branch Crop Sci. Soc., 54(12),* 19-31.

Kumar, R., Sharma, S. & Prasad, R. (2013). Yield, nutrient uptake and quality of stevia as affected by organic sources of nutrient. *Commun. Soil Sci. Plant Anal., 44,* 3137-3149.

Li, G. C. & Mahler, R. L. (1995). Effect of plant material parameters on nitrogen mineralization in a mollisol. *Commun. Soil Sci. Plant Anal., 26(11-12),* 195 -198.

McCauley, A., Clain, J. & Jacobsen, J. (2009). Commercial fertilizers and soil amendments. Nutrient management, a self-study course from MSU extension continuing education series. Montana State University. Montana State, USA.

Muscolo, A., Bovalo, F., Gionfriddo, F. & Nardi, F. (1999). Earthworm humic matter produces auxin-like effects on *Daucu carota* cell growth and nitrate metabolism. *Soil Biol. Biochem., 31,* 1303 -1311.

Nematian, A., Ghoushchi, F., Farnia, A., Ariapour, A. & Mashhadi, A. B. M. (2010). The effect of planting density and nitrogen fertilizer on active substances in medicinal plant *Aloe vera* L. *Iranian J. Medici. Aromat. Plants, 10:* 85-89.

Ogundare, S. K. (2011). Influence of influence of organic manure types on soil physicochemical properties and yield of maize in Ejiba, Nigeria, PhD thesis, Department of Crop, Soil and Pest Management. Federal University of Akure, Nigeria.

Olatunji, O. & Oboh, V. U. (2012). Growth and yield of okra and tomato as affected by pig dung and other manure issue for economic consideration in Benue state. *Niger. J. Soil Sci., 22(1),* 103-107.

Park, Y. I. & Lee, S. K. (2006). (eds). New perspectives on aloe, Springer.

Parvez, M. S., Islam, M. R., Begum, M. S., Rahman, M. J. & Abedin, 2008. Integrated use of manures and fertilizers of maximizing the yield of BRRI dhan30. *J. Bangladesh Soci. Agric. Sci. Technol., 5(1&2),* 257-260.

Prabha, M. L., Jayraaj, I. A., Jayraaj, R. & Rao, D. S. (2007). Effective of vermicompost on growth parameters of selected vegetable and medicinal plants. *Asian J. Microbiol Biotechnol. Environ. Sci., 9,* 321- 326.

Raghothama, K. G. (1999). Phosphate acquisition. *Annual Review of Plant Physiology and Plant. Molecular Biol., 50,* 665-693.

Ramabai, N., Regina, A., Devika, R. & Joseph, C. A. (1992). Genetic variability and association of characters in medium duration rice genotypes. *Oryza, 29,* 19-22.

Ramesh, K., Singh, V. & Ahuja, P. S. (2007). Production potential of *Stevia rebaudiana* (Bert.) Bertoni under intercropping systems. *Archives Agron. Soil Sci., 53,* 443-58.

Saha, R., Palit, S., Ghosh, B. C. & Mittra, B. N. (2005). Performance of Aloe vera as influenced by organic and inorganic sources of fertilizer supplied through fertigation. *Acta Hort., 676,* 171-175.

Wilhelm, W. W., Ruwe, K. & Schlemmer, M. R. (2000). Comparisons of three Leaf Area Index Meters in a Corn Canopy. *Crop Sci., 40,* 1179-1183.

Zaman, M. M., Nahar, K., Chowdhury, T. & Chowdhury, M. A. H. (2017). Growth, leaf biomass yield of stevia and postharvest soil fertility as influenced by different levels of poultry manure. *J. Bangladesh Agril. Univ., 15(2),* 212-218.

Zarandi, T. S., Rezvani, M. P. & Jahan, M. (2011). Comparison of organic and chemical fertilizers on yield and essential oil content of *Ocimum basilicum*. *J. Agric. Ecol., 2(1),* 82-70.

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