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Full Length Research Paper

Effect of Fruit Peel Formulated Natural Fertilizer on Soil Fertility and Plant Growth

Nandini Rohatgi* and Adrija Saha[#]

[#]Associate Professor, Department of Dietetics & Nutrition, NSHM Knowledge Campus, Kolkata. [#]Corresponding author E-mail: adrija.saha@nshm.com

Previous affiliation: The work was carried out at our previous affiliation.
*M.Sc Food & Nutrition Student, J D Birla Institute, 11, Lower Rawdon Street, Kolkata-19.
[#]Assistant Professor-II, J D Birla Institute, 11, Lower Rawdon Street, Kolkata-19.

Abstract

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This investigation was conducted to determine the effect of fruit peels (sweet lime, pomegranate and banana peels) as natural fertilizer on soil fertility and plant growth. The peels were dried, ground and incorporated into the soil in various combinations using the method of backyard composting. Fenugreek plants were grown in the prepared soil samples. Results showed that the application of fruit peel formulations led to improved soil quality and increased plant growth. Improved soil fertility was attributed to increased organic matter and higher microbial count of the soil samples because of the application of fruit peel formulated fertilizer. Hence, the study concluded have significant environmental benefits over the use of chemical fertilizers.

Keywords: Backyard composting, Banana peels, Natural fertilizer, Pomegranate peels, sweet lime peel.

Highlights

1. Fruit Peels as Effective Organic Fertilizers: The study demonstrated that fruit peels (banana, sweet lime, and pomegranate) can be composted and used as organic fertilizers, significantly enhancing soil fertility and plant growth, especially in Formulation 6.
2. Improved Nutrient Profile in Soil: Compost enriched with fruit peels showed higher levels of essential nutrients such as nitrogen, potassium, and carbon compared to both positive (chemical fertilizer) and negative (plain soil) controls, promoting a more sustainable nutrient cycle.
3. Positive Impact on Plant Growth: Plants grown in soil treated with fruit peel compost (especially Formulation 6) exhibited better growth in terms of height, density, and yield (more branches and seed pods) than those in control groups, indicating enhanced plant health and productivity.
4. Environmental and Economic Benefits: Using fruit waste for composting reduces the dependency on chemical fertilizers, minimizes fossil fuel usage, and helps in managing biodegradable solid waste efficiently, making it a cost-effective and eco-friendly alternative.
Potential Risks of Imbalanced Formulations: The study also highlighted that excessive use of certain peels (e.g., banana in Formulation 3) can lead to potassium toxicity and nutrient imbalance, underscoring the importance of balanced formulation for optimal soil health.

Introduction

Over the past few decades, the world's population has been growing at an exponential rate. By 2100, there will be 11.2 billion people on the planet, up from the estimated 5.3 billion in 1990 (United Nations Population Division, 2019). Food production must constantly rise to feed the world's expanding population, but arable land is still a finite resource.

To boost crop productivity, farmers have so expanded their usage of chemical fertilizers (Vanlalmawii and Awasthi, 2016). Despite increasing crop yields, the extensive and heavy use of chemical fertilizers has degraded the environment by negatively impacting soil fertility, soil microbiology, and the quality of surface and ground water (Kapoor et al., 2015). Furthermore, burning fossil fuels is necessary to produce chemical fertilizers, which has resulted in air pollution and the depletion of non-renewable resources. Additionally, the amount of organic food waste produced annually has expanded tremendously along with the growth in food production and consumption.

Agricultural science has been searching for several ways to get out of this predicament. Currently, scientists recommend using organic fertilizers instead of chemical ones since they are a good substitute that can increase soil fertility and agricultural productivity without harming the environment. Organic fertilizers are less expensive, non-toxic, readily available, and less reliant on fossil fuels than chemical fertilizers. Furthermore, soil microbes gradually break down organic fertilizers into simpler components, which causes these components to be fully fixed into the soil and increase soil fertility (Meenambal et al., 2003). This also enables the plants to use these components completely for an extended amount of time. Furthermore, the creation of organic fertilizers serves as a nutrient-rich medium for plant growth and a soil amendment, with the goal of managing, recycling, and converting biodegradable solid waste. To increase agricultural production and successfully manage waste disposal challenges, this research focuses on turning organic food wastes (such fruit peels) into useful compost.

Methodology

Soil (alluvial), earthen pots, chemical fertilizer, and fenugreek seeds were bought from the local nursery. Sweet lime (*Citrus limetta*) peels, pomegranate (*Punica granatum*) peels and banana (*Musa paradisiaca*) peels were collected from various households. The fruit peels were washed, sun-dried and ground to a coarse powder. The pH of the fruit peels was determined, and various formulations were made. The compost was prepared by using the method of backyard composting. The fruit peels were added to the soil in a ratio of 1:9. Three formulations were prepared from the three different fruit peels, and four formulations were made using blends of different combinations between them. Positive control comprised of only chemical fertilizer and the negative control lacked all of them. The details of all the formulations are mentioned in Table 1. The initial characteristics of the soil was loamy texture, greyish brown color with high water holding capacity and a pH of neutral to slightly alkaline (7.6).

The prepared soil mixture was kept in open for 15 days to allow complete decomposition of the organic matter (fruit peels) into mature and stable compost. During this duration, the soil mixture was turned manually daily to allow proper aeration. After 15 days, fenugreek seeds were soaked overnight and sown in the prepared soil. The soil was watered twice a day, and the growth of the plants was monitored daily.

Studying Characteristics of Soil

The following parameters were studied:

- Soil pH**:** The pH of the soil was determined by shaking the soil in distilled water (1:9) for 30 minutes. The pH was measured using pH meter.
- Soil texture**:** The soil texture was determined by the Feel Analysis Method.
- Bulk density**:** The bulk density of the soil was determined by calculating the ratio of weight of oven-dried soil to its bulk volume.
- Soil porosity**:** It was calculated by the method given in Soil Quality Test Kit Guide by USDA-NRCS (1999).
- Specific gravity**:** IS 2720, Part III/Sec 1 (1980) test method given by BIS was used.
- Water holding capacity**:** It was determined by calculating the ratio of mass of water absorbed by the oven dried soil to the weight of oven-dried soil.
- Moisture content**:** IS 2720, Part II (1973) test method given by BIS was used.

Nutrient levels in soil: After 3 months of preparation of the formulations, 3 soil samples (positive control, negative control and formulation 6) were sent to the laboratory for analysis of total nitrogen, phosphorus, potassium and carbon levels in the soil. The procedure that was followed were as follows:

- **Total nitrogen levels:** IS 14684 (1999) test method given by BIS was used.
- **Available phosphorus levels:** The method given in the Methods of Soil Analysis, Part II (Soil Science Society for America) was used.
- **Potassium levels:** The method given in the Methods of Soil Analysis, Part II (Soil Science Society for America) was used.
- **Carbon levels:** IS 2720 (Part 22) 1972 test method given by BIS was used.

Rate of plant growth: The growth of plants was regularly monitored to determine the most effective formulation. After 6 months, the length of the plants was determined by randomly selecting 10 plants from each formulation and measuring the length between the tip of the shoot to the tip of the root. The mean value was calculated and expressed in centimeters. The experiment was conducted in the summer season mostly.

Table 1: Composition of soil formulations.

Formulations (in 2 kg soil)	Ground sweet lime peel (g) (SL)	Ground pomegranate peel (g) (P)	Ground banana peel (g) (B)	Chemical fertilizer (g)
Negative control	—	—	—	—
Positive control	—	—	—	10
Formulation 1	200	—	—	—
Formulation 2	—	200	—	—
Formulation 3	—	—	200	—
Formulation 4 (SL:P:B = 1:1:1)	67	67	67	—
Formulation 5 (SL:P:B = 2:1:1)	100	50	50	—
Formulation 6 (SL:P:B = 1:2:1)	50	100	50	—
Formulation 7 (SL:P:B = 1:1:2)	50	50	100	—

Results and Discussion

pH of fruit peels and soil pH: The pH of sweet lime and pomegranate peels was found to be acidic due to the presence of sufficient quantities of organic acids whereas the pH of banana peels was found to be alkaline due to the presence of large quantities of potassium which is alkaline in nature (Sagar *et al.*, 2018) Table 2.

To provide a variety of nutrients to the plants, various formulations were made in such a manner to attain a desirable neutral soil pH.

Soil pH is very important as it affects the availability of nutrients to plants as well as the survival of microorganisms in the soil which, in turn, would affect the soil fertility (Gentili *et al.*, 2018). There was only a slight difference between the pH of various soil formulations when compared with the control. Table 3. This may be because little quantities of fruit peels were added in large quantities of soil.

Physical properties of soil: The texture of all the soil samples was found to be clay loam, which is the most suitable soil type for plant growth (Finch *et al.*, 2014). Studies have shown that texture is one of the most stable attributes of the soil and it is only slightly modified by cultivation practices (USDA –NRCS, 1999). The bulk density of formulation 6 was found to be the lowest. Bulk density reflects the soil's ability to function for structural support, water and nutrient movement. Hence, the lower bulk density of formulation 6 may be due to increased porosity of the soil because of application of fruit peel formulation (USDA-NRCS, 1999). Amongst the two controls, bulk density of positive control was found to be low which may be due to the presence of large pores (i.e., cracks and fissures) in the soil (Massah and Azadegan, 2016). The soil porosity of formulation 6 was found to be the highest. Soil porosity is widely recognized as one of the best indicators of the soil structure quality as it helps in determining various properties of soil such as the movement of water, air and other fluids, the ease of penetration of roots, the transport of nutrients to the plant roots and the survival of soil microorganisms (Pagliai and Vignozzi, 2006; Nimmo, 2005). The application of organic materials to the soil greatly enhances the soil porosity by stabilizing the pore walls against the destructive forces of water and assuring the functionality of the pores (Marinari *et al.*, 2000). The moisture content and water holding capacity of the soil was found to be higher in formulation 6 as compared to the two controls. This may be due to increased porosity and improved soil structure because of application of fruit peel formulations (Malik *et al.*, 2014). Although increased porosity and lower bulk density was observed in case of positive control, the water holding capacity and moisture content was found to be low. This may be due to the formation of elongated pores (cracks and fissures) in the soil because of application of chemical fertilizers (Vengadaramana and Thairiyanathan, 2012). The specific gravity of formulation 6 was found to be the lowest. This may be due to increased microbial activity, increased porosity, lower bulk density and improved soil structure because of increased organic content of the soil. Increased porosity, lower bulk density, increased water holding capacity, higher moisture content and low specific

Table 2: pH of fruit peels.

Fruit peels	pH
Sweet lime peels	4.6
Pomegranate peels	4.03
Banana peels	7.97

Table 3: Soil pH.

Soil formulations	pH
Positive Control	7
Negative Control	7.6
Formulation 1	7.2
Formulation 2	7.15
Formulation 3	7.8
Formulation 4	7.63
Formulation 5	7.41
Formulation 6	7.27
Formulation 7	7.66

Table 4: Physical properties of soil.

Soil formulation	Bulk density (g/cm^3)	Soil porosity (%)	Water holding capacity (%)	Moisture content (%)	Specific Gravity
Positive Control	1.15	56.7	27.2	29.31	2.6
Negative Control	1.39	47.3	34.5	33.45	2.73
Formulation 6	0.86	68	42.86	40.2	2.1

gravity improves the soil structure and quality thereby, resulting in improved plant growth. The physical properties of soil are mentioned in Table 4.

Nutrient levels in soil: After 3 months, the nitrogen, phosphorus, potassium and carbon levels of the soil were determined.

- **Total nitrogen levels:** The total nitrogen content of formulation 6 was higher when compared with the two controls. The incorporation of organic matter in formulation 6 led to an increase in the proportion and activity of nitrogen-fixing bacteria in the soil. These bacteria had resulted in increased nitrogen fixation in legumes and hence enhanced plant metabolism (Sreekumar, 2014). Although the chemical fertilizer contains huge amounts of nitrogen, the nitrogen levels were found to be low in positive control. The application of chemical fertilizers may have led to a decrease in the activity of microorganisms responsible for nitrogen fixation which may have resulted in increased nitrogen losses from the soil (due to volatilization, leaching, etc.) (Zhou *et al.*, 2017). (Table 5)
- **Available phosphorus levels:** The available phosphorus level in formulation 6 was found to be higher than the negative control but lower than the positive control. The increase in phosphorus content of formulation 6 may be due to the incorporation of large quantities of organic matter and the desirable pH of the soil as availability of phosphorus depends upon the pH of the soil (Pan *et al.*, 2012). High phosphorus content in the positive control may be because the chemical fertilizer contains huge quantities of phosphorus in readily available form. Such high levels of phosphorus is undesirable as it might lead to zinc immobilization and deficiency in plants along with phosphorus toxicity thereby, resulting in stunted plant

Table 5: Nutrient levels in soil.

Soil formulation	Total nitrogen (mg/kg)	Available phosphorus (mg/kg)	Potassium (mg/kg)	Carbon (%)
Positive Control	1.76	389.05	133	0.57
Negative Control	0.59	3.92	79	0.66
Formulation 6	5.31	30.88	328	2.95

Table 6: Root:Shoot ratio.

Soil formulations	Root: Shoot ratio
Positive Control	0.38
Negative Control	0.2
Formulation 6	0.21

growth (Soltangheisi *et al.*, 2013). (Table 5)

- **Potassium levels:** The potassium content of formulation 6 was found to be higher than the two controls. The incorporation of organic matter into the soil significantly increases the activity of soil microorganisms. Hence, the increase in potassium levels may be due to the degradation of enormous quantities of potassium present in the banana peels (Hussein *et al.*, 2019; Sreekumar, 2014). The potassium content of the negative control was found to be satisfactory. This may be because of the presence of sufficient quantities of naturally occurring potassium in the soil. Most heavy soils (clay soils) contain adequate quantities of naturally occurring potassium (Barre *et al.*, 2008). (Table 5)

- **Carbon levels:** The carbon level in formulation 6 was found to be higher than the two controls. The increase in carbon content may be because of the incorporation of organic matter into the soil. Organic materials are a rich source of simple and complex sugars and dietary fibre which makes them a good source of food for the microorganisms (Ahmed and Basumatary, 2008). Hence, addition of organic material into the soil may have increased the activity of microorganisms that are responsible for degradation of complex organic matter into simpler and stable forms, thereby increasing the reduced carbon pools in the soil (Fliessbach & Mader, 1997; Pathak *et al.*, 2017). The carbon levels were found to be low in the positive control which may be since chemical fertilizers are a poor source of organic matter (Rai *et al.*, 2014). (Table 5)

Plant growth: Formulation 6 had achieved maximum plant growth. Furthermore, the plants grown in this formulation 6 were denser, studier and consisted of a greater number of branches and seed pods as compared to other soil formulations. Hence, this formulation was found to be quite suitable for plant growth which may have been due to increased soil fertility and improved plant nutrition because of the application of fruit peels in the soil (Sagar *et al.*, 2018). Moreover, amongst the two controls, the plant growth seen in positive control was more when compared with the negative control. Least growth was observed in Formulation 3 and the plants died before completing their life cycle. This may have been due to the toxic build-up of potassium in the soil. Banana peels are rich in potassium and the potassium level in this formulation may have been much higher than that desired for plant growth. This may have resulted in build-up of potassium in the soil thereby, resulting in cation imbalance and deficiency of other minerals (such as magnesium and calcium) in the soil (Arienzo *et al.*, 2009). The plant growth rate is often determined by measures such as root: shoot ratio. The root: shoot ratio was found to be normal for formulation 6 and was high for positive control. High root: shoot ratio for positive control may have been due to increased competition amongst the plant roots because of unfavorable soil environment and limited availability of nutrients in the soil thereby, resulting in restricted growth of plant shoots (Beets *et al.*, 2007; Maskova and Herben, 2018).

Conclusion

The results of the study showed that adding a natural fertilizer made from fruit peels to the soil improved soil fertility and promoted plant growth. To improve soil fertility and encourage plant growth, fruit peels can be used as a natural fertilizer. The lack of infrastructure made it impossible to determine the zinc levels in the soil samples. In addition to enhancing soil health, the use of fruit peel

based fertilizer offers significant environmental benefits. It promotes sustainable waste recycling by converting biodegradable kitchen waste into valuable agricultural input. Furthermore, it helps reduce reliance on chemical fertilizers, thereby minimizing soil and water pollution and supporting eco-friendly farming practices.

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