EVALUATING FRUIT PEEL WASTE AS A BIOSTIMULANT FOR ENHANCED SEED GERMINATION, SEEDLING GROWTH, AND PLANT DEVELOPMENT: A SUSTAINABLE APPROACH

[1]Mrs.B.Rukmini Devi, [2]Dr.P.Shivakumar Singh
[1&2] Bharatiya Engineering Science and Technology Innovation University (BESTIU),Mandrol Lake, Gownivaripalli, Gorantla Mandal, Sri Satya Sai District, Andhra Pradesh – 515231.
Correspondence: B.Rukmini Devi,Assistant Professor of Botany, New Government Degree College for Women Golconda,Hyderabad, Telangana.
E-Mail: 2024wpbot003@bestiu.edu.in

Abstract:

Food production is a serious challenge to sustainable agriculture due to the increasing global population. Routine farm practices that can rely heavily on synthetic fertilizers can lead to environmental damage including soil infertility, water pollution, and greenhouse gas emissions. Hence, it is imperative to find and use alternatives that are eco-friendly, cost-effective and sustainable to enhance the productivity of crops without exacerbating environmental issues further. Fruit Peel Waste (FPW), a rich and abundant by-product of the fruit processing industry, is largely wasted. But it has potential to be used as a bio stimulant in sustainable agriculture. In this paper, the impact of fruit peel waste extract (FPWE) on seed germination, seedling growth and plant development of mustard (*Brassica juncea*) has been investigated.The fruit peel waste extract, rich in phytonutrients and antioxidants was applied to any crop seed and seedling and it was found that it enhances the germination and growth of seedlings as well as plant development. The extract from fruit peel waste has the ability to stimulate growth, offering a sustainable, eco-friendly and alternative method to synthetic growth promoters in sustainable agriculture.

Key words: Biostimulant, Phytonutrients, Seed germination rates,Seedling vigor,Sustainable Agriculture

Introduction:

The food waste generated in the global food system is estimated to be 1.3 billion tons per year, with fruit-processing industries accounting for 25–30% of the total fruit mass as peel waste [FAO]. The peels are typically thrown in landfills or open dumps, where they break down under anaerobic conditions, producing methane, leachate, and VOC's which contaminates soil, water, and air. Although considered to be “waste”, the fruit peel is a biochemically dense source of macro-nutrients, micronutrients, organic acids, polyphenols and plant growth promoting compounds.

The peels of banana (*Musa acuminata*) are rich in 40% – 45% potassium, dietary proteins and polyunsaturated fatty acids for the support of cell division and turgor [Sonia et al., 2014]. Orange (*Citrus sinensis*) peels contain N, Mg and ascorbic acid; and pomegranate (*Punica granatum*) peels contain the amounts of phosphorus, calcium and iron, which have a role in energy transfer and chlorophyll synthesis [Jariwala & Syed, 2017]. The peels of watermelon (*Citrullus lanatus*) are rich in potassium, organic matter, and micronutrients which help enhance soil water-holding capacity [Pathak et al., 2020]. The fruit peels have been reported to be useful for agronomic purpose by several studies; Jariwala and Syed (2017) reported that citrus and banana peels in powdered form help maintain soil pH and provide Fe, Ca, and Zn; Panwar (2015) reported that the fruit peels of bananas had the potential of improving soil fertility and reducing pollution in the environment. Application of fruit peel extract showed significant increase in the height of fenugreek and leaf area, according to the study conducted by Mercury et al. (2014).

Yet there are two major knowledge gaps. First, most studies test individual peel varieties, or liquid extracts, with few comparative, dose dependent studies conducted on multiple peel species under similar conditions. Second, the amount of peel powder that is phytotoxic is still unknown, because of the possible effect of high organic matter on N immobilization and osmotic stress.

With the high cost of fertilizers and the deterioration of soil quality due to the use of chemical products, low-cost and locally available products, which can recycle waste and preserve soil quality, are needed now.

Mustard (*Brassica juncea L.*), is an important oilseed crop in India which is pH sensitive and is sensitive to early nutrient availability. It is also a model crop due to its speed of germination and short growth cycle, which allows the assessment of biostimulants.

Based on this, the present study was conducted to:

1. Study the effect of banana, orange, pomegranate and watermelon peel powders on the germination and growth of B. juncea seeds.
2. Decide on a dose (5g, 10g, 15g or 20g per pot) that will be optimal.
3. Assess changes in soil pH following peel amendment.

It is hypothesized that moderate application of fruit peel powder will improve seed germination and vigor of seedlings and also help to improve soil acidity, which paves the way for sustainable agriculture with minimal use of synthetic fertilizer and promotes the concept of circular economy in agriculture.

Objectives

1. To test the effect of fruit peel extract on the germination of seeds.
2. To find the optimum concentration.
3. To make a comparison between the treated and untreated plants.
4. To study the effect on soil pH.
5. To encourage sustainable farming and waste recycling.

Literature Review:

The environmental burden of fruit peel waste is also significant, with the potential to be valorized.

The global food loss and waste is estimated at 1.3 billion tons per year, and fruits and vegetables account for ~45% of it [FAO]. Peel waste from fruit processing industries accounts for 25-30% of the fruit mass, which has a high amount of organic content, but is acidic and has a high biological oxygen demand [Awasthi et al., 2016]. The disposal of such waste in landfills encourages anaerobic decomposition, which results in leachate pollution of soil and groundwater and methane emissions. More than 50% of the horticultural waste is not used in India [Pathak et al. 2020]. This has been the motivation behind “waste-to-wealth” approaches that involve transforming agro-waste into compost, biochar, enzymes and biostimulants [Sharma & Ranjan, 2018].

Organic amendments, bio stimulants and plant derived organic amendments Biostimulants are compounds that when applied to plants or soil, increase nutrient uptake, stress resistance and crop quality without providing any nutrients [Du Jardin, 2015]. The fruit peels contain phytohormones, polyphenols, amino acids, and humic substances, which are known to act as biostimulants as they stimulate plant root growth, chlorophyll production and soil microbial activity [Calvo et al., 2014]. In contrast to manufactured fertilizers, organic amendments have slow nutrient release and enhance soil aggregation and water holding capacity [Singh et al., 2017].

The macro- and micronutrient content is preserved in fruit peels. The banana peel has been found to contain about 40–45% of K, 8–10% N, proteins, and amino acids which have a positive effect on cell elongation [Sonia et al., 2014; Adeniyi et al., 2019]. Orange peel has a high content of N, Mg and Ca which increases the chlorophyll and antioxidant properties [Jariwala & Syed, 2017]. Pomegranate peel provides P, Ca, Fe and phenolics which enhance the fertility of soil and microbial biomass. WMP acts as a source of potassium (K), organic carbon and micro-nutrients, and enhances soil moisture holding capacity [Pathak et al., 2020]. The nutrient availability in legumes is also reported to be improved by buffering soil pH due to the use of organic amendments from fruit wastes [Dwivedi et al., 2015; Panwar, 2015].

Fruit peels are known to have growth-promoting activities and these activities are supported by studies. Jariwala and Syed found that soil pH was neutralized towards neutral range, available Fe, Ca and Zn was enhanced to improve the growth of Phaseolus due to the application of powdered citrus, banana and pomegranate peels. According to the results of the studies carried out by Mercury et al., the extracts of mixed fruit peels increased fenugreek height by 28% and leaf area by 22% compared to the control. At 10g kg^{-1} soil, Panwar found that banana peel increased maize biomass and decreased soil acidity. Sonia et al. reported an increase in the vigor of tomato seedlings in the presence of banana peel powder, which is attributed to the presence of the elements K and amino acids. Most studies, however, have studied individual peels or liquid extracts; and dose-dependent responses are still not well studied.

Soil pH influences the availability of nutrients, particularly for *Brassica juncea* which has an optimum pH range of 6.0–7.5. Fruit peels contain carbonates and organic acids in high quantities and are natural buffers for the pH. Jariwala and Syed observed that citrus peel powder increased the pH of soil from 5.8 to 7.2 in 30 days. Awasthi et al reported that the composted fruit waste decreased the acidity and improved the solubility of P. K and Ca carbonates [FAO] in the watermelon and orange peels help to reduce the Al toxicity and improve microbial activity in acidic soils.[2021]

Research gap and study objective:

The nutritional value of single species of fruit peel has been determined, but multiple species of fruit peel have not been evaluated in comparison using graded doses under uniform conditions. Moreover, the phytotoxic level of peel powder is hardly known, because excessive amounts of organic matter can lead to N immobilization and osmotic stress [Calvo et al., 2014]. There is limited information available regarding early growth parameters and soil pH changes of oilseed crops, such as *B. juncea*, when grown with solid peel powder. Hence, the study aims to evaluate banana powder (B), orange powder (O), pomegranate powder (P) and watermelon powder (W) at three different application rates (5, 10, 15 and 20 g/2 kg soil) to find most effective dose of banana, orange, pomegranate and watermelon peels for sustainable mustard production.

Experimental Design, Materials and Methods:

A pot experiment was laid out in Completely Randomized Design (CRD) with 4 fruit peel treatments + 1 control, and 3 replications per treatment. Each replicate = 1 pot with 10 seeds. Treatments per 1 kg soil

Materials:

• Fresh fruit peels (banana, orange, pomegranate, watermelon)

- Mustard seeds (Brassica juncea)
- Garden soil
- Pots
- pH paper or digital pH meter
- Universal indicator

Procedure for Fruit peel Powder Preparation:

1. Peels washed with tap water + 0.1% NaCl for 2 min to remove microbes.
2. Shade-dried 7–10 days until constant weight, moisture <10%.
3. Ground in a mechanical grinder and sieved through mesh to get fine powder.
4. Powder stored in airtight zip-lock bags at room temperature.

Crop Culture: 1. 1 kg soil mixed with respective peel powder as per treatment and filled in pots. Control received soil only.

2. 10 seeds sown at 1 cm depth per pot. Irrigated to 70% field capacity immediately after sowing.
3. Pots maintained at 28±3°C, 65–75% RH under natural photoperiod.
4. Watering is done daily with equal volume using a measuring cylinder.

Experimental Design

Solid Biostimulant Treatments (Powder Form) T0 –
Control (Soil only)
T1 – Soil + 5 g peel powder T2
– Soil + 10 g peel powder T3 –
Soil + 15 g peel powder T4 –
Soil + 20 g peel powder

Ten mustard seeds were sown per pot and later thinned to five healthy plants.

Application Method

1. Seeds were sown in the soil supplemented with respective quantities of fruit peel powder.
2. After germination, seedlings were treated weekly.
3. Control plants received only water.

Parameters Studied:

- Germination percentage
- Shoot length (cm)
- Root length (cm)
- Seedling height
- Soil pH

Germination Percentage (GP):

Germination percentage was calculated using the formula:
Recorded daily from 3 DAS (Days After Sowing- DAS) until no new germination for 3 consecutive days.
Final GP taken at 7 DAS for mustard.
Seed considered germinated when radicle ≥ 2 mm emerged [ISTA].[2023]

$$GP\ (\%) = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds}} \times 100$$

Shoot Length(cm): At 21 DAS, 10 random seedlings per replication were uprooted, washed.
Shoot length measured from cotyledonary node to shoot apex using ruler.

Root Length (cm): The same seedlings used for shoot measurement were used . Root length was measured from cotyledonary node to tip of primary root. Lateral roots excluded.Roots were blotted dry before measurement to avoid elongation due to water uptake.

Seedling height (cm): Seedling Height= total length of seedling. It was obtained by summing shoot length +Root length for each seedling.

Seedling Height (cm):Shoot length (cm)+ Root Length (cm)

Soil pH Testing:

Materials: Soil sample, distilled water, pH meter or pH indicator paper, beaker, stirrer. Procedure:

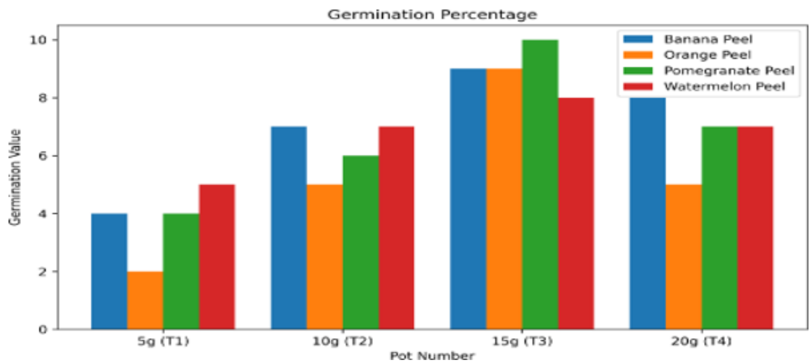
- Take 10 g of air-dried, sieved soil in a beaker.
- Add 25 mL of distilled water (1:2.5 soil-water ratio).
- Stir for 30 minutes and let it settle for 10 minutes.
- Measure pH using a calibrated pH meter (or dip pH paper for rough estimate).

Result Analysis and Discussion : The present study shows that banana, orange, pomegranate and watermelon peel wastes, or natural biostimulants, can be used as an effective natural biostimulant for improving seed germination and early seedling growth in *Brassica juncea*. The various treatments tested with 15 g per pot T3 gave the best germination percentage, shoot length, root length and seedling vigour and is useful for maintaining desirable soil pH. This means that moderate concentrations of fruit peel waste provide important macro- and micronutrients, organic acids and phytohormones to improve the nutrient availability and buffer the soil pH, while high concentrations can cause osmotic stress or phytotoxicity.

Seed Germination Percentage:

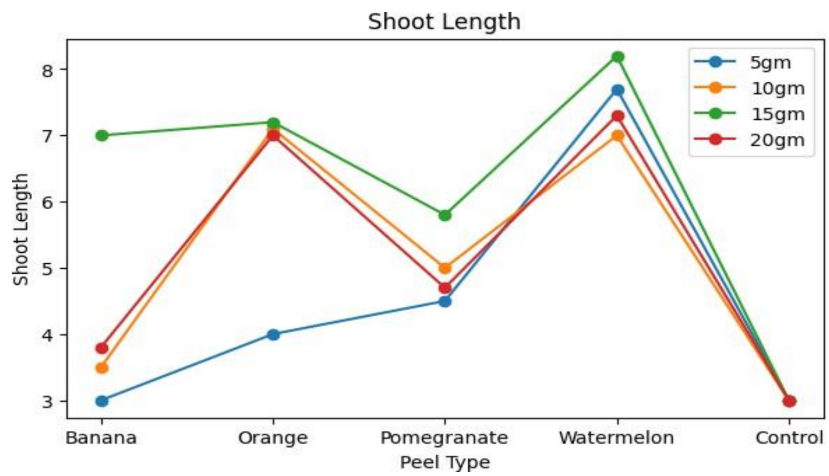
Pot Number	Banana Peel	Orange Peel	Pomegranate Peel	Watermelon Peel	Control pot
5gm T1	4	2	4	5	

10gm T2	7	5	6	7	1
15gm T3	9	9	10	8	
20gm T4	8	5	7	7	



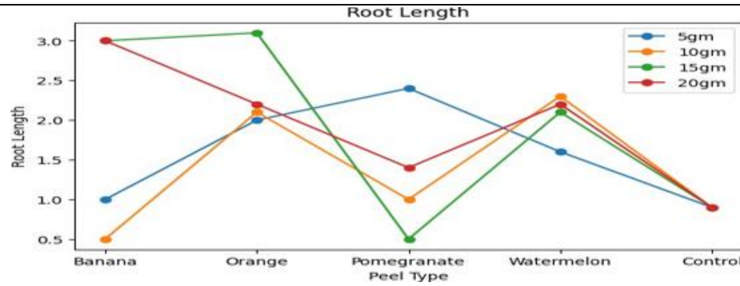
Shoot Length:

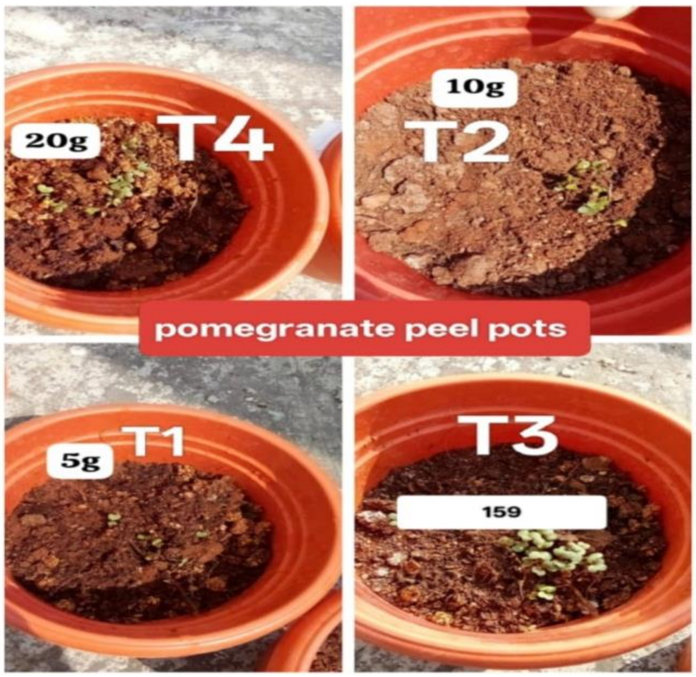
Peel Type	5gm	10gm	15gm	20gm
Banana	3.0	3.5	7.0	3.8
Orange	4.0	7.1	7.2	7.0
Pomegranate	4.5	5.0	5.8	4.7
Watermelon	7.7	7.0	8.2	7.3
Control	3.0	3.0	3.0	3.0

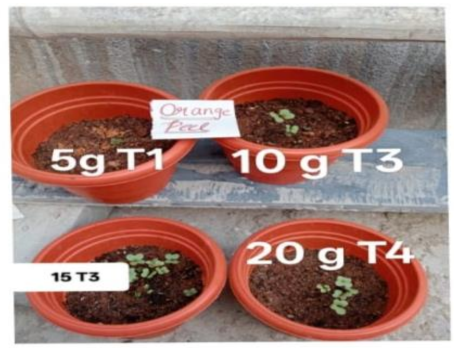


Root Length:

Peel Type	5gm	10gm	15gm	20gm
Banana	1.0	0.5	3.0	3.0
Orange	2.0	2.1	3.1	2.2
Pomegranate	2.4	1.0	0.5	1.4
Watermelon	1.6	2.3	2.1	2.2
Control	0.9	0.9	0.9	0.9







Determination of Soil pH

Type of Pot	Pot1 (5g)	Pot2 (10g)	Pot3 (15g)	Pot4 (20g)
Banana Peel	7.0-7.5	7.0-7.5	7.0-7.5	7.0-7.5
Orange Peel	7.5-8.0	7.5-8.0	7.5-8.0	7.5-8.0
Pomegranate Peel	7.0-7.5	7.0-7.5	7.0-7.5	7.0-7.5
Watermelon	8.0-8.5	8.0-8.5	8.0-8.5	8.0-8.5
Control Pot	5.5-6.0	-	-	-

Conclusion: The results revealed that fruit peel waste at 15 g pot can be recommended as a cheap and eco-friendly biostimulant to improve the germination and early vegetative growth of oilseed crops. Future studies should be directed towards long term field trials, nutrient release kinetics and impact of fruit peel biostimulants on soil microbial communities and the yield parameters under different agro-climate conditions.

Both solid and liquid preparations of fruit peel waste were significantly superior to the control indicating the potential of fruit peel waste as an eco-friendly alternative to synthetic fertilizers. Therefore, the circular economy and sustainable agriculture concepts were closely tied in by using agricultural waste as biostimulants, since it decreased environmental pollution due to landfilling peels while simultaneously being a reuse of organic resources as added-value input in crop production.

Acknowledgement:
The authors are grateful to the Principal , New Government Degree College for Women, Golconda, Hyderabad, for providing laboratory facilities and institutional support to carry out this research work. The authors also sincerely thank the Vice Principal for her valuable guidance and constant encouragement throughout the study. Heartfelt gratitude is extended to the Zoology Lecturer for her technical assistance, and to the students of New Government Degree College for Women, Golconda, for their help in conducting the experiments.

References:

1. Awasthi, M.K., Pandey, A.K., Khan, J., & Wang, Q. 2016. Nutrient recovery from organic waste through composting.Bioresource Technology, 200, 590–596. https://doi.org/10.1016/j.biortech.2015.10.013

2. Adeniyi, O.R., Ojo, D.P., & Adedokun, A.O. 2019. Banana peel as a source of potassium for vegetable production in tropical soils. International Journal of Vegetable Science, 25(4), 321–329.

3. Brar, S.K., & Saraf, C.S. 2021. Fruit waste valorization for sustainable agriculture: A circular economy approach.Waste and Biomass Valorization, 12(5), 2301–2315.

4. Calvo, P., Nelson, L., & Kloepper, J.W. 2014. Agricultural uses of plant biostimulants: A review of the literature. Agronomy for Sustainable Development, 34(1), 81–104. https://doi.org/10.1007/s13593-013-0148-0

5. Du Jardin, P. 2015. Plant biostimulants: Definition, concept, main categories and regulation.Scientia Horticulturae, 196, 3–14. https://doi.org/10.1016/j.scienta.2015.09.021

6. Dwivedi, S., Sahrawat, K.L., & Upadhyay, R.M. 2015. Nutrient management in Vigna radiata through organic amendments: A review.Legume Research, 38(2), 145–152.

7. Food and Agriculture Organization [FAO]. 2021.Food Loss and Waste Database. Rome: FAO.http://www.fao.org/food-loss-and-food-waste/en/

8. Government of India, Ministry of Food Processing Industries. 2020.Waste Generation from Fruit Processing Industries in India. New Delhi: MoFPI.

9. ISTA. (2023). International rules for seed testing. International Seed Testing Association.

10. Jariwala, H.J., & Syed, H.S. 2017. Study on use of fruit peels for nutrient enhancement of soil. International Journal of Scientific Research, 6(3), 351–354.

11. Mercury, M., Singh, R., & Patel, K. 2014. Effect of fruit peel extract on growth and yield of Trigonella foenum-graecum L.Journal of Plant Science, 2(5), 206–210.

12. Panwar, N.R. 2015. Banana peel: A novel substrate for agriculture and energy production.

Agricultural Reviews, 36(2), 127–131. https://doi.org/10.5958/0976-0741.2015.00019.3

13. Pathak, L., Zhang, L., & Wang, Y. 2020. Sustainable agriculture through organic waste recycling: A review on fruit peel valorization. Journal of Cleaner Production, 245, 118836. https://doi.org/10.1016/j.jclepro.2019.118836

14. Rouphael, Y., & Colla, G. 2020. Plant biostimulants: Rationale, current state and future perspectives. Frontiers in Plant Science, 11, 40. https://doi.org/10.3389/fpls.2020.00040

15. Sharma, A., & Ranjan, R. 2018. Waste to wealth: Valorization of fruit and vegetable waste for biostimulant production.Current Science, 115(8), 1467–1474.

16. Singh, A., Sharma, R., & Kumar, S. 2017. Effect of organic amendments on growth, yield and soil properties of legumes.Journal of Plant Nutrition, 40(10), 1398–1408. https://doi.org/10.1080/01904167.2017.1288856

17. Sonia, N.S., Dasan, A., & Rajasree, S. 2014. Banana peel powder: A potential source of nutrients and bioactive compounds for food and agricultural applications.Journal of Food Science and Technology, 51(12), 3527–3530. https://doi.org/10.1007/s13197-012-0861-5

18. Turan, M., Ekinci, M., Yildirim, E., Güneş, A., Karagöz, K., Kotan, R., & Dursun, A. 2014. Plant growth-promoting rhizobacteria improved growth, nutrient, and hormone content of cabbage seedlings.Turkish Journal of Agriculture and Forestry, 38(3), 327–333.

19. Zandonadi, D.B., Santos, M.P., Dobbs, L.B., & Olivares, F.L. 2014. Plant proton pumps as targets for biostimulant action.Scientia Agricola, 71(5), 360–364.