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Shirisha Karupakula

Agronomy disciplinel, School of Natural Resource Management, College of Post Graduate Studies in Agricultural Sciences (Central Agricultural University), Umiam, 793103, Meghalaya, India

Ram Vishram

Agronomy disciplinel, School of Natural Resource Management, College of Post Graduate Studies in Agricultural Sciences (Central Agricultural University), Umiam, 793103, Meghalaya, India

Bhargav Reddy Maram

Agronomy disciplinel, School of Natural Resource Management, College of Post Graduate Studies in Agricultural Sciences (Central Agricultural University), Umiam, 793103, Meghalaya, India

Corresponding Author:**Shirisha Karupakula**

Agronomy disciplinel, School of Natural Resource Management, College of Post Graduate Studies in Agricultural Sciences (Central Agricultural University), Umiam, 793103, Meghalaya, India

Temporal dynamics of dry matter accumulation and crop growth in sweetcorn under residual phosphorus and crop-residue mulching

Shirisha Karupakula¹, Ram Vishram², Bhargav Reddy Maram³

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ABSTRACT

This study highlights the residual effect of organic mulch and rate phosphorus (P) on succeeding sweetcorn crop. Phosphorus is the essential nutrient, should be applied at the optimum levels to meet the crop requirement. The integrated effect of organic mulch and rate P improves the performance of sweetcorn, conservation of soil moisture, increase in availability of nutrient might be underlying causes. Therefore, experiment was conducted with three organic mulch levels (un mulch (UM), rice straw mulch (RSM) and maize stover mulch (MSM) and four rates of P (P_{120} (120 kg P ha⁻¹), P_{80} (80 kg P ha⁻¹), P_{40} (40 kg P ha⁻¹) and P_0 (0 kg P ha⁻¹). RSM has significantly reported highest plant height, dry matter accumulation CGR, LAI and yield attributes over MSM and UM. RSM and MSM has reported 13.26 and 8.84% higher plant height, 18.55 and 8.0% higher dry matter accumulation, 20.55 and 8.78% higher CGR, 10.99 and 5.43% higher LAI and 21.39 and 14.70% higher green cob yield, respectively over the un mulch treated plot. Amon the rate of P P_{120} has reported significantly highest growth and yield parameters over P_{80} , P_{40} and P_0 . P_{120} has reported 13.42% higher plant height, 15.31% higher dry matter accumulation, 15.52% higher CGR, 10.18% higher LAI and 14.76% higher cob yield compared to P_0 treatment

Keywords: Organic mulch, Rate of phosphorus, Rice straw mulch, Maize stover mulch, Cob yield

1. Introduction

Maize (*Zea mays*) ranks as third important crop among the cereals globally, following wheat and rice (Ram *et al.*, 2023) [14]. It occupies 8 % of the total cereal area and contributes to 25% of global cereal production (Pinjari *et al.*, 2017) [12]. Known as the "queen of cereals" worldwide, maize possesses the highest genetic potential among all cereal crops (Tollenaar *et al.*, 2006) [17]. Sweet corn (*Zea mays saccharata* L.) is a subgroup of corn (*Zea mays*) that is categorized based on kernel traits. The distinction between sweet corn and standard corn primarily lies in the genes that influence starch production in seed endosperm; in sweet corn, one or more simple recessive alleles modify the carbohydrate composition of the endosperm, resulting in elevated levels of water-soluble polysaccharides and reduced starch content. The kernels of sweet corn have a significantly sweeter flavour compared to regular corn. The revenue generated from sweet corn is comparatively higher than grain maize. In the year 2023-2024, India's overall maize output reached 33.5 million metric tons from a cultivated area of 9.98 million hectares (Kumari *et al.*, 2025) [7]. In the North East region of India, maize has the potential to emerge as an important crop, with its share of total area coverage ranking second after rice. The utilization of sweet corn and its byproducts has significantly risen globally in past thirty years. The primary products consist of the sweet corn pericarp and its endosperm tissue. As the endosperm has both sugar and starch, it possesses a syrupy taste until it fully develops and dries out more than other types of corn (Ghuman *et al.*, 2024) [3]. Sweet corn is a lucrative crop because of its greater market value in relation to other typical corn types. Nevertheless, effective production necessitates effective management and marketing. Robust market connections and a strong grasp of consumer preferences can assist farmers in optimizing their earnings from the production of sweet corn. Efficient management strategies involve selecting appropriate varieties, prompt sowing and gathering, and enforcing pest and disease management mainly nutrient management. The profit margins of maize production can be significantly impacted by management, and improving yield requires improving management, especially with regard to fertilisation. Due to its involvement in many physiological processes like photosynthesis, respiration, and energy transfer, phosphorus (P) is a crucial macronutrient for plant growth and development [Chowdhury *et al.*, 2021 [2]]. It is essential for ATP synthesis, phospholipids, and nucleic acids all of which is required for DNA replication, cell division, and the storage and transfer of energy [Khan *et al.*, 2009 [5]]. A sufficient amount of P is required for healthy root development, plant growth, and an ideal crop output. P is regarded as the second most important nutrient after nitrogen for improving crop productivity. Moreover, it aids in the rapid formation and expansion of roots, enhancing crop tolerance to agricultural diseases. However, P deficiency in soils is a widespread issue that limits crop production and global food security [Yadav *et al.*, 2017 [22]]. Thus, the use

of P fertilizers is essential to replenish P levels in soils and meet the nutritional demands of crops. The studies have found that excessive P addition does not increase light-saturated photosynthetic rates or growth rates understory plants. Furthermore, excessive P application can have negative effect on surface water that disrupt the functioning of biological systems [Minhas, 2020 [10]]. Additionally, excessive P can run off into nearby bodies of water, leading to an overgrowth of algae and pathogenic bacteria that reduce oxygen levels in the water and make it unsafe for drinking or recreation [Pierzynski and Logan, 1993 [11]]. Therefore, it is crucial to determine the current P levels in the soil, the adequate P levels needed by the crop, and amount of fertilizer that should be applied to soil to meet crop's optimal P needs before suggesting a P fertilizer. These results emphasize the need to consider the effects of P addition not only on individual plants but also on the functioning and diversity of plant communities [Mao *et al.*, 2021].

The integrated use of crop residue mulch and phosphorus fertilizer is one of the option for mitigating the reliance on excess P utilization. The usage of crop residue as a mulch may provide many beneficial effects, such as improvement of soil biological, physical properties, nutrient cycling, conservation of soil moisture, etc. The use of crop residue as mulch and incorporation helps to aid the availability nutrients, ultimately improve crop yield and reduce the reliance on synthetic fertilizers. When inorganic nutrients and organic waste are treated jointly in tests, the combinatorial effect outweighs the beneficial effects of each component alone [Titab *et al.*, 2011 [16]]. Grain production may be impacted by the negligent management of agricultural waste accumulation in several agricultural nations [Huang *et al.*, 2012 [4]; Zheng *et al.*, 2012 [25]]. When compared to the total amount of returning stover, a suitable amount of plant waste greatly boosts yield, increases leaf area and chlorophyll concentration, and protects plants from habitation [Bunna *et al.*, 2011 [1]]. By releasing organic acids to solubilise conserved insoluble soil P or by substituting them with affordable and sustainable natural P sources, such as agricultural crop wastes, the use of organic nutrient sources can reduce dependency on expensive chemical P fertilisers. Previous studies demonstrated that combining plant residues such as sarson and sesbania with phosphate sources can enhance soil quality [Ullah *et al.*, 2023]. Similarly, it has found that applying sugarcane filter mud (SFM) [Salman *et al.*, 2023], chicken manure [Marlina *et al.*, 2017 [9]], and household trash together to crop brassica residues improves plant development and yield. The combined and combinatorial effects of applying phosphorus and crop stover as mulch (henceforth, straw return) have not assessed in sweetcorn. This study set out to determine whether a mix of crop residues and phosphorus sources could be effective for improving sweet corn's growth and production. In order to do this, we tested the possible advantages of this strategy in an experiment on a tiny piece of land, to study the residual effect of mulch which has applied as mulch in potato crop, which was not decomposed fully has taken advantage to study incorporation of residual mulch and P on potato crop.

2. Materials and Methods

The field experiment was conducted over a 2- year period during summer season of 2023 and 2024 at experimental farm College of Post Graduate Studies in Agricultural Science, Umiam, Meghalaya. The study area is located in the district's mild tropical hill zone, which has a subtropical humid climate with heavy monsoon rainfall and minimal winter rainfall. The area receives 2450 mm of rainfall annually, with about 80-85% of being received between May and October. The average minimum and maximum temperatures range from 12.5

to 21.5 °C and 21.9 to 29.5 °C, respectively, and the monsoon typically starts in the first two weeks of May or the first week of June and lasts until the second fortnight of September or the first week of November.

2.1 Treatment details

The experiment was conducted over split-plot design, consists of 3 residual organic mulch levels (which was mulched during preceding winter potato crop), viz., M₀: un mulch, M₁: rice straw mulch (RSM), M₂: maize straw mulch (MSM) under main plot, four subplot levels include residual rate of phosphorus (P) (applied during preceding winter potato crop) and the experiment was replicated three times. Sweetcorn crop was grown during summer season following winter potato crop in same research plot to study effect of rate of P and organic mulch levels which was applied during winter potato crop. Therefore, residual P and mulch effects which was applied in potato was studied on the succeeding sweetcorn crop. The sweetcorn variety Sugar-75 has been taken for the study. The growth duration of sweetcorn was reported 98 and 97 days during 2023 and 2024, respectively. Ride and furrow method of cultivation was adopted with ridges 50 cm apart and plant to plant was 20 cm apart (50×20 cm), resulting plant density of 100000 plants ha⁻¹. The major nutrients, N (120 kg ha⁻¹) and K (80 kg ha⁻¹) were applied through urea and MOP, respectively. However, P has not applied to study the residual effect of P applied in preceding potato crop. Same experimental plot has used to conduct the research for two years of the experiment.

The growth parameters, viz., plant height, dry matter, CGR, LAI was studied at 15 days interval during crop duration. Plant height of 10 tagged plants was measured with metre tape up to the tallest leaf length. For dry matter measurement, 3 plants from each plot are cut up to the base and chopped into small parts oven dried for 2 days at 60°C, then observations were recorded later averaged to a single value. LAI was measured with the help of planimeter. The yield, parameters, viz., no of cobs, cob weigh, cob length, green cob yield, stover yield was measured at the time of harvest.

Results

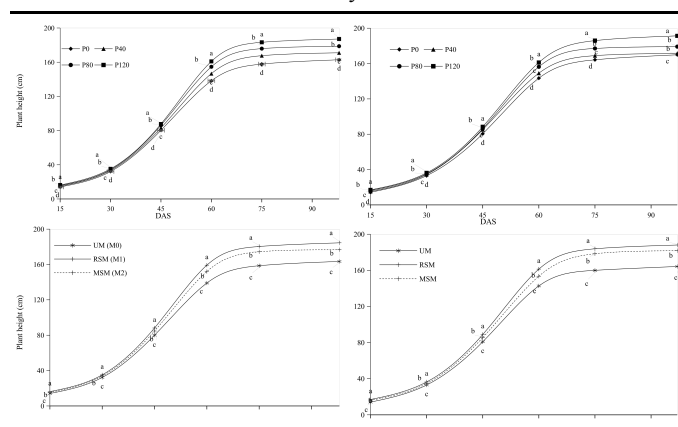
3.1 Plant height

Residual P and organic mulch had significantly affected plant height during entire growing season of sweetcorn (Fig.1.). The rice straw mulch (RSM (M₁)) has reported significantly highest plant height over the entire growing period over maize straw mulch (MSM (M₂)), in turn reported significantly highest over un mulch (UM (M₀)). Plant height reported increasing trend up to 60 DAS, thereafter increasing at slower rate. RSM has recorded highest plant height (184.50 (2023) and 188.03 cm (2024)) followed by MSM (176.71 (2023) and 181.75 cm (2024)) followed by UM (163.45 (2023) and 164.24 cm (2024)). Among the residual rate of P application P₁₂₀ has reported significantly highest over P₈₀, P₄₀ and P₀. P₁₂₀ has recorded highest plant height of 187.11 and 191.33 cm, during 2023 and 2024 respectively followed by P₈₀ (178.67 (2023) and 179.14 cm (2024)), P₄₀ (170.96 (2023) and 171.65 cm (2024)) and P₀ (162.80 (2023) and 169.91 cm (2024)).

Figure 1. Residual effect of Organic mulch (un mulch (UM), rice straw mulch (RSM) and maize stover mulch (MSM) and rate of P (P₁₂₀ (120 kg P ha⁻¹), P₈₀ (80 kg P ha⁻¹), P₄₀ (40 kg P ha⁻¹) and P₀ (0 kg P ha⁻¹) on plant height of sweetcorn during 2023 (a, b) and 2024 (c, d). Note: Different lower-case alphabets within same legend

(continued on next page)

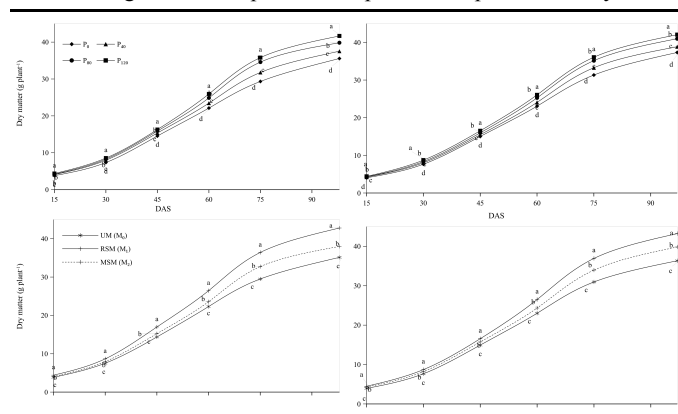
indicate significant difference at $p = 0.05$ as per DMRT post-hoc analysis



3.2 Dry matter and CGR

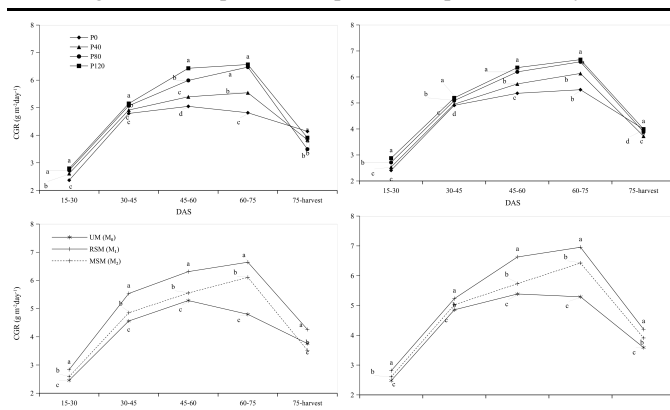
The residual effect of rate of P and organic mulch on dry matter is represented in Fig.2. The dry matter content was increased with the crop duration up to 60 DAS, thereafter, increased at a decreasing rating up to harvest of the crop. RSM has reported significantly higher dry matter over MSM and UM. During the of harvest, RSM reported highest dry matter accumulation (42.80 (2023) and 43.23 g plant⁻¹ (2024)) followed by MSM (38.00 (2023) and 38.92 g plant⁻¹ (2024)) and UM (35.14 (2023) and 36.34 g plant⁻¹ (2024)). Among the residual rate of P application P_{120} has reported significantly highest dry matter accumulation over the other treatments. At the time of harvest P_{120} has reported highest dry matter (41.67 and 42.05 g plant⁻¹) followed by P_{80} (39.83 and 40.97 g plant⁻¹), P_{40} (37.53 and 38.85 g plant⁻¹) and P_0 (35.55 and 37.32 g plant⁻¹).

Figure 2. Residual effect of Organic mulch (un mulch (UM), rice straw mulch (RSM) and maize stover mulch (MSM) and rate of P (P_{120} (120 kg P ha⁻¹), P_{80} (80 kg P ha⁻¹), P_{40} (40 kg P ha⁻¹) and P_0 (0 kg P ha⁻¹) on dry matter of sweetcorn during 2023 (a, b) and 2024 (c, d). Note: Different lower-case alphabets within same legend indicates significance at $p = 0.05$ as per DMRT post-hoc analysis



Crop Growth Rate (CGR) has increased up to 45 days after sowing then maintained constant up to 75 DAS, then declined up to harvest during both the experimental years. Over the entire growing period, highest CGR was recorded during 60-75 DAS over all the treatments. RSM has reported highest CGR (6.65 and 6.95 g m⁻² day⁻¹) over MSM (6.11 and 6.42 g m⁻² day⁻¹) and UM (4.80 and 5.29 g m⁻² day⁻¹). Among the residual rate of P application P_{120} has reported significantly highest CGR over other treatments during both experimental years. During 60-75 DAS, P_{120} (6.57 and 6.67 g m⁻² day⁻¹) has reported highest CGR followed by P_{80} (6.47 and 6.58 g m⁻² day⁻¹), P_{40} (5.54 and 6.13 g m⁻² day⁻¹) and P_0 (4.82 and 5.51 g m⁻² day⁻¹).

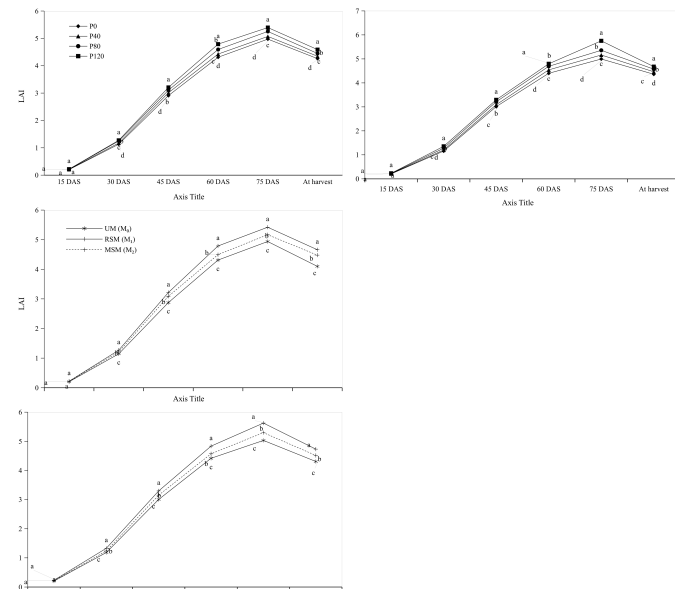
Figure 3. Residual effect of Organic mulch (un mulch (UM), rice straw mulch (RSM) and maize stover mulch (MSM) and rate of P (P_{120} (120 kg P ha⁻¹), P_{80} (80 kg P ha⁻¹), P_{40} (40 kg P ha⁻¹) and P_0 (0 kg P ha⁻¹) on CGR of sweetcorn during 2023 (a, b) and 2024 (c, d). Note: Different lower-case alphabets within same legend indicate significance at $p = 0.05$ as per DMRT post-hoc analysis



3.3 LAI

LAI was reported increasing trend up to 75 DAS, thereafter has decreased up to harvest (Fig.3.). Residual organic mulch levels had significantly affected LAI, with RSM has reported significantly highest LAI followed by MSM and UM over the entire growing period. During 75 DAS, RSM (5.42 and 5.63) has reported highest LAI followed by MSM (5.17 and 5.30) and UM (4.94 and 5.03). Among the rate of P , P_{120} (5.40 and 5.75) treatment has reported significantly highest LAI, followed by P_{80} , (5.25 and 5.36), P_{40} (5.07 and 5.16) and P_0 (4.97 and 5.00).

Figure 4. Residual effect of Organic mulch (un mulch (UM), rice straw mulch (RSM) and maize stover mulch (MSM) and rate of P (P_{120} (120 kg P ha⁻¹), P_{80} (80 kg P ha⁻¹), P_{40} (40 kg P ha⁻¹) and P_0 (0 kg P ha⁻¹) on LAI of sweetcorn during 2023 (a, b) and 2024 (c, d). Note: Different lower-case alphabets within same legend indicate significance difference at $p = 0.05$ as per DMRT post-hoc analysis



3.4 Yield parameters

The residual effect of organic mulch and rate of P is presented in Table.1. RSM has shown significantly highest cob yield and yield parameters over MSM and UM. RSM has reported highest cob length (24.23 and 24.93 cm) over MSM (22.70 and 23.44 cm) and UM (21.76 and 22.24 cm). Cob weight has also reported highest value in RSM (84.50 and 86.65 cm) followed by MSM (77.91 and 79.54 cm) and UM (71.23 and 72.58 cm). Green cob yield was reported highest

under RSM (4.52 and 4.56 t ha⁻¹) followed by MSM (4.24 and 4.34 t ha⁻¹) and UM (3.64 and 3.84 t ha⁻¹). Green fodder yield followed the same trend. Harvest Index was not significantly affected by organic mulch levels.

Rate of P has significantly influenced yield and yield attributes of sweetcorn crop (Table.1.). P_{120} (23.96 and 24.88 cm) treatment has reported significantly highest cob length over P_{80} (23.29 and 23.95 cm), P_{40} (22.58 and 22.98 cm) and P_0 (21.77 and 22.34 cm).

P_{120} (82.52 and 83.46 g plant⁻¹) has reported highest cob weight per plant followed by P_{80} (79.83 and 80.51 g plant⁻¹), P_{40} (76.10 and 78.70 g plant⁻¹) and P_0 (73.08 and 75.69 g plant⁻¹). Green cob yield was reported significantly highest under P_{120} (4.37 and 4.57 t ha⁻¹) followed by P_{80} (4.19 and 4.40 t ha⁻¹), P_{40} (4.09 and 4.12 t ha⁻¹) and P_0 (3.90 and 3.89 t ha⁻¹). The results for green fodder yield have followed similar trend. Harvest index of sweetcorn crop was not affected significantly by rate of P.

Table.1. The residual effect of (un mulch (UM), rice straw mulch (RSM) and maize stover mulch (MSM) and rate of P (P_{120} (120 kg P ha⁻¹), P_{80} (80 kg P ha⁻¹), P_{40} (40 kg P ha⁻¹) and P_0 (0 kg P ha⁻¹) on yield parameters of sweetcorn crop

	Cob length		Cob weight (g plant ⁻¹)		Green cob yield (t ha ⁻¹)		Green fodder yield (t ha ⁻¹)		Harvest Index	
Residual organic mulch										
UM (<i>M</i> ₀)	21.76b	22.24b	71.23c	72.58b	3.64c	3.84c	5.41b	5.66b	40.19a	40.41a
RSM (<i>M</i> ₁)	24.23a	24.93a	84.50a	86.65a	4.52a	4.56a	6.24a	6.45a	42.03a	41.38a
MSM (<i>M</i> ₂)	22.70ab	23.44ab	77.91b	79.54ab	4.24b	4.34b	6.02a	6.30a	41.31a	40.66a
Residual rate of <i>P</i>										
<i>P</i> ₀	21.77b	22.34c	73.08c	75.69c	3.90c	3.89c	5.65b	5.93c	40.79a	39.61a
<i>P</i> ₄₀	22.58ab	22.98bc	76.10bc	78.70bc	4.09bc	4.12bc	5.86ab	6.07bc	40.96a	40.44a
<i>P</i> ₈₀	23.29a	23.95ab	79.83ab	80.51ab	4.19ab	4.40a	5.95ab	6.20ab	41.32a	41.49a
<i>P</i> ₁₂₀	23.96a	24.88a	82.52a	83.46a	4.37a	4.57a	6.11a	6.35a	41.64a	41.73a

Note: Different lower-case alphabets within same column indicate significance at $p = 0.05$ as per DMRT post-hoc analysis

Discussions

Increased agricultural productivity has been linked to organic mulching practices, particularly live and leaf litter mulching. The fundamental causes may include mulching offers, reducing excessive evaporation to guarantee steady water supply for plants, inhibiting weed growth, promoting thermal balance, and enhancing nutrient cycling after breakdown and decomposition [Wu *et al.*, 2016 [21]]. Because of their higher capacity to recycle nutrients, living and leaf litter mulching specifically outperforms paddy straw mulching in terms of increasing crop yields. By strengthening soil fertility, this improved nutrient cycling ensures that plants receive nutrients continuously [Petrikovszki *et al.*, 2021 [13]]. The experiment has reported the significantly highest growth and yield under mulched conditions especially rice straw mulch over un mulch. Khan *et al.*, 2024 reported that chichpea residue has reported more ear m⁻² (7.2), grains ear⁻¹ (442), 1000 grain weight (319.28 g), and grain yield (8993 kg ha⁻¹) over wheat residue and control. Mulching could also promote the root growth (root length, root diameter, root surface area, and root volume), and also average root biomass by 17.27% (Yang *et al.*, 2023). Ghuman *et al.*, 2024 [3] reported that bulk density was not substantially impacted by the various tillage and residue retention combinations; nevertheless, conventional tillage with residue had lower BD values than other tillage techniques. The explanation for this could be the addition of organic matter through the assimilation of crop wastes. Adequate P availability is necessary for maintaining photosynthetic efficiency and normal crop growth [39,40]. Within an ideal range, a number of studies have reported a positive correlation between P application and crop yield. But adding excess P above a certain point doesn't boost production any more, in fact, it might cause a plateau or drop in yield along with resource waste and environmental hazards [Vance *et al.*, 2010 [19]; Kumari *et al.*, 2021 [6]]. Beyond the ideal range, excessive P application hinders the synthesis and transport of organic molecules, interferes with plant physiological processes, and decreases tolerance to biotic and abiotic stressors, all of which eventually limit crop output [Lü *et al.*, 2025 [8]]. The highest grain yields were recorded at 90 kg-P₂O₅ ha⁻¹ in 2021 (9520 kg ha⁻¹) and 60 kg P₂O₅ ha⁻¹ in 2022 (12,880 kg ha⁻¹) (Yang *et al.*, 2025) [24]. Overall, this study suggest integrated use of crop residue mulch has significantly increased growth and yield of sweetcorn crop even as a residual effect of preceding potato crop.

The results of this study indicate that the benefits (and necessity) of combining organic mulch (rice straw mulch) with adequate residual phosphorus application for sweetcorn growth and productivity are very strong. Clearly, the crop may have the potential to reach a level beyond that which could be achieved by relying on conventional practices without consideration of the residual value of nutrients and organic inputs. The consistent performance of the RSM + P_{120} combination in sweetcorn based cropping systems would support its adoption in sweetcorn based cropping systems, in our view. Such sustainable inputs should be the priority in future nutrient management strategies to maximize yield as well as soil fertility and system resilience over time.

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