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# Effect of fertility levels and mulching on nutrient mobilisation in soil and plants of short duration rainfed sweet corn (*Zea mays* var. *saccharata* (Sturtev.) L.H.Bailey)

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## Abstract

India has a huge potential for rice residue, which if burnt causes a substantial environmental loss. Similarly, the rainfed sweet corn (*Zea mays* var. *saccharata* (Sturtev.) L.H.Bailey) cultivation often faces the problem of nutrient deficiency, especially phosphorus (P). Therefore, the present study was conducted at agriculture research form, Banaras Hindu University, Varanasi, Uttar Pradesh, India and in the years 2013 and 2014. To evaluate the effects of nutrient levels and mulch are helpful in enhancing crop and soil nutrient status and balance. Therefore, an experiment was conducted keeping three fertility levels ($F_1$: 75 % recommended dose of fertiliser (RDF), $F_2$: 100 % RDF and $F_3$: 125 % RDF) and two mulches ($M_1$: soil mulch and $M_2$: rice straw mulch at 6 t ha$^{-1}$) in main plots while three P levels ($P_1$: recommended dose of phosphorus (RDP) (100 % $P_2O_5$), $P_2$: 150 % RDP and $P_3$: 200 % RDP) in sub-plots. The highest level of RDF (125 % RDF) though recorded better crop nutrient status (kernel N 1.619–1.632 %, P 0.240–0.246 %, K 0.184–0.191 % and Zn 30.250–30.449 mg kg$^{-1}$) and total nutrient uptake in various plant parts (N 2.9–5.3 %, P 9.5–9.6 %, K 7.1–7.7 % and Zn 2.0–2.1 %) but that could not differ from 100 % RDF. Residual nutrients (N 7.1–7.2 %, $P_2O_5$ 9.0–7.5 %, $K_2O$ 7.0–6.2 % and Zn 3.4–1.8 %) in soil were also higher in 125 % RDF. Similarly, 200 % RDP recorded better nutrient status and uptake in plants except Zn content which was higher at the least P rate (65 kg ha$^{-1}$). Rice residue mulch (6 t ha$^{-1}$) was superior to soil mulch in terms of plant nutrient status, uptake and residual soil nutrients. However higher fertiliser rate created successive apparent negative nitrogen (N) and zinc (Zn) balance. Similarly, successive application of phosphorus revealed more Zn loss from soil (5.2–5.5 %).

**Keywords :** nutrient balance; nutrient content; rainfed conditions; sweet corn; soil nutrient status

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## 1. Introduction

Maize (*Zea mays* L.) is a versatile crop that serves as a staple human food as well as animal feed, fodder and industrial raw material. However, the economic gain from maize is relatively low, pushing its cultivation into fragile rainfed environments by farmers having poor socio-economic condition where moisture conservation had prime importance. Recently immature ears of sweet corn (*Zea mays* var. *saccharata* (Sturtev.) L.H.Bailey) after roasting, boiling or canning (1, 2) emerged as new, alternative and profitable food sources, especially for the affluent society, in luxury hotels and theaters. Sweet corn cultivation popularising among farmers dwelling in outskirts of the cities and peri-urban areas due to its high sugar and low starch content. It has a great market potential and values in India (3, 4). Its short duration makes it suitable for harsh weather and scanty rainfall and fits well in various rainfed cropping system of India. Additional benefits of green straw after harvesting for green ears used for animal feed (2).

Since its exhaustive nature, balanced and adequate supply of nutrients (a function of soil type, initial nutrient status, rate of application and climatic variation) for harnessing higher production per unit area required (4). Maize responds well to fertilisers and a crop producing 6.1 t ha$^{-1}$ grain yields requires 168 kg nitrogen (N), 57 kg phosphorus pentoxide ($P_2O_5$), 135 kg potassium oxide ($K_2O$) and 30 kg zinc (Zn) ha$^{-1}$ (5). To safeguard soil health and fertility, judicious use of plant nutrients required for bumper crop production as they

alone contribute 40–60 % in the crop yield (6). Soils of rainfed semi-tropics in India is susceptible to nutrient depletion thus may require higher fertilisation. Yield and yield components of sweet corn responded positively to increasing levels of nitrogen, phosphorus and potassium (NPK) (7). However, questions remain regarding its responses in rainfed ecosystem? Thus, we evaluated the different doses to standardise the crop response in such situations. It is well known that rainfed crops have low nutrient use efficiency. Various factors contributed to the low fertiliser use, including scarcity of water resources and the economics of its use (8). Understanding yield dependence on growth factors and combinations of factors is indispensable in planning desirable inputs. A case of special agronomic interest is the combined effects of nutrient and moisture conservation for profitable sweet corn production in scarce environment (9).

The application of crop residues, such as rice straw, as a soil surface mulch to enhance moisture conservation represents a dual agricultural approach that integrates traditional empirical knowledge with contemporary scientific innovation in rainfed farming systems. There is the huge potential for rice residue mulching in India as 44.5 Mt is surplus (10) out of which around 23 Mt burnt annually (11) in the Indo-Gangetic plains (IGP) region. This results in significant social and human health problems. The loss of ecosystem services of 126 $ ha$^{-1}$ and the social cost of 450 $ million per annum in the region (11) is noted due to burning. The adverse effect of moisture stress on the productivity of rainfed corn can be minimised by the use of crop residue as mulch besides soil status helps to better understand this approach (12–16). Though mulching is historic practice but not been well understood in rainfed conditions yet especially in terms of nutrient availability and dynamics in short sweet corn cropping period. Some researchers suggested the immobilisation and lesser availability to main crop and better availability for succeeding crop (17–19). Nutrient uptake, its concentration and partition and soil status after harvesting are the better indicator in understanding this regards. Furthermore, the exact mechanisms behind how short-term mulching whether using soil or straw conserves water and boosts crop yields are still not fully understood. Limits in experimental condition, mulch application studies are still simple comparisons of crop yield from soil and straw mulch. This experiment is an attempt to understand whether rice straw or soil mulch is more effective for rainfed sweet corn?

Phosphorus, a key nutrient, plays a crucial role in quality sweet corn production as it is required in higher P fertilisation. Phosphorus deficiency or lesser availability significantly reduced sugar content due to conversion into starch through biochemical process ultimately affecting the quality of sweet corn (20–23). Inorganic phosphate ions (Pi) heavily regulate starch biosynthesis. Adequate inorganic phosphates minimise this conversion process (24). Thus, agronomic management through higher phosphoric fertilisation can enhance sweet corn quality. However, P availability is often limited by moisture scarcity (25). Therefore, this experiment was conducted to evaluate higher doses of P in rainfed conditions with the objectives a) either straw or soil much is helpful in short cropping period of sweet corn and its effect on nutrient dynamics. b) What would be response of fertilisers in nutrient availability and uptake by crops. c) What would be soil nutrient status of soil after harvest of the crop.

## 2. Materials and Methods

### Experimental location and weather

Experimental studies were conducted to compare the different levels of primary nutrients including micronutrients and mulch techniques in wet season of two consecutive years 2013 and 2014. The experiment was located at Varanasi district which lies in the North-East Plain Zone of Eastern Uttar Pradesh at 25˚32’ N latitude and 82˚97’ E longitude and at an elevation of 86 m above the mean sea level in the north Indo-Gangetic alluvial plains of India which falls under a sub-tropical, especially in semi-arid to sub-humid type of climate. Normal period for the onset of monsoon is the 3$^{rd}$ week of June which normally ceases by the end of September. The mean weekly values of weather data during the period of experimentation obtained from meteorological observatory at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University are presented in (Fig. 1). The total rainfall received during investigation was 648.9 mm (2013) and 628.7 mm (2014). During 2013, 150.2 mm precipitation took place in 35$^{th}$ Standard Meteorological Week (SMW) coinciding with tassel emergence stage of the crop. However, 259.7 mm rain took place in 29$^{th}$ SMW of 2014 coinciding with the germination stage. During experimental period, temperature was normally between 34.9–24.3 °C in 2013 and 36.7–24.3 °C in 2014, respectively. The average evaporation of 3.8 mm day$^{-1}$ was similar during both years. The relative humidity varied between 66–93 % and 56–93 % respectively in both the experimental period. The lowest minimum relative humidity was attained during 37 and 39$^{th}$ standard week during 1$^{st}$ year and 2$^{nd}$ year, respectively.

### Soil properties

The test crop was grown under sweet corn-mustard cropping system. Composite soil samples from (0–15 cm depth) were randomly collected from the experimental field with the help of screw auger before start of the experiment in each season. The soil samples were air dried and analysed for chemical properties. The soil of the study area was sandy clay loam in texture with pH of 7.38 and 7.40, electrical conductivity (EC) of 0.34 and 0.32 dSm$^{-1}$, organic carbon (OC) (0.33 and 0.32 %), available N (190.13 and 187.58 kg ha$^{-1}$), available $P_2O_5$ (19.11 and 18.77 kg ha$^{-1}$), available $K_2O$ (182.17 and 180.31 kg ha$^{-1}$) and available Zn (0.47 and 0.49 mg kg$^{-1}$) in 2013 and 2014 wet seasons, respectively.

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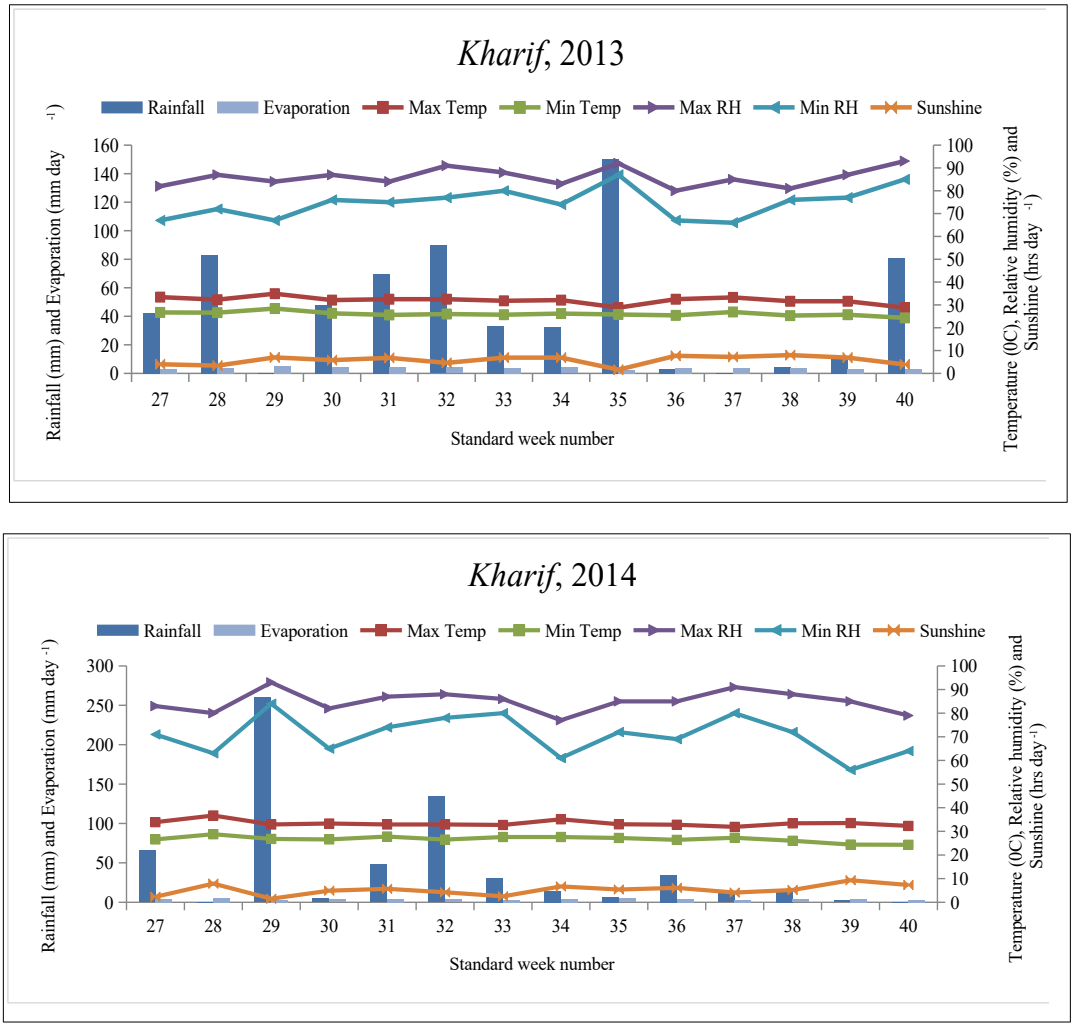



**Fig. 1.** Standard meteorological week wise weather data during crop season.

## Experimental design, layout and farm operations

The experiment was laid out in split plot design with 3 replications accommodate purely through randomisation. The treatments comprised combinations of two factors i.e. three fertility levels (25 % less than recommended dose of fertiliser (RDF), RDF and 25 % more than RDF) and 2 types of mulches (soil mulch and rice straw mulch at 6 t $ha^{-1}$) in main plots and 3 P levels (recommended dose of phosphorus (RDP), 150 % RDP and 200 % RDP) in sub-plots. The recommended dose of fertilisers was 150.0 kg N + 65.0 $P_2O_5$ + 65.0 kg $K_2O$ + 10.0 kg Zn $ha^{-1}$ which varied as per treatments. The rice straw mulch at 6 t $ha^{-1}$ was spread between line spacing on the soil surface uniformly in accordance with treatments 5 days after the sowing of crop. Soil mulch was also created by using dryland weeder five days after the sowing of crop. The doses of different nutrients viz. N, K, Zn and P were applied as per treatments through urea, diammonium phosphate (DAP), muriate of potash (MOP) and zinc oxide (ZnO). Half of the recommended dose of nitrogen and full doses of P, K and Zn were applied as basal and rest half dose of N was top dressed through urea in two equal splits at knee high and tassel emergence stages under optimum soil moisture condition. Sweet corn variety 'Madhuri' was sown manually by opening furrow with kudal at 60 × 25 cm at about 5 cm depth with seed rate of 8 kg $ha^{-1}$ and sowing was done on 8$^{th}$ July and 10$^{th}$ July in 2013 and 2014, respectively. Gap filling was followed 10 DAS by transplanting the sweet corn seedling of same physiological age in experimental field as to maintain the optimum population wherever necessary. Pre-emergence application of Atrazine at 1.5 kg a.i. $ha^{-1}$ was done to control initial weed flushes uniformly to all the experimental plots. Furadon at 5 kg a.i. $ha^{-1}$ applied to check the attack of shoot borers (*Chilo partellus* and *Sesamia inferens*) at 30 DAS. Drainage was provisioned wherever needed. The sweet corn cobs were harvested at green stage as per maturity and green fodder after cob harvesting was done on 23$^{rd}$ and 26$^{th}$ September of both the years, respectively i.e. 83 and 87 days taken from sowing.

## Plant analysis

Treatment wise sweet corn kernels, cob husk and remaining green fodder samples were collected for chemical estimation of N, P, K and Zn. The respective samples were first sun dried and then dried in an oven at 70 °C finally ground thoroughly in a Willey mill to pass through 30 mesh sieve. Samples thus obtained were preserved and sealed in a labeled container for

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chemical analysis. Plant sample (0.5 g) taken for analysis were digested and N content in sweet corn kernel, cob husk and green fodder was estimated using modified Kjeldahl method; phosphorus content by Vandomolybdo-phosphoric acid yellow colour method using the Barton's reagent; K content by Flame Photometer (14). The zinc content determined with the help of Atomic Absorption Spectrophotometry method (25). The uptake of N, P, K (kg $ha^{-1}$) and Zn (g $ha^{-1}$) by sweet corn kernels, cob husk and green fodder were obtained by multiplying nutrient content (%) of sweet corn kernels, cob husk and fodder with their respective yields (26). Total nutrient uptake judged by addition of partitioned nutrient in crop.

### Soil sampling and analysis

Soil samples from 0–15 cm depth were collected after harvest of sweet corn from each plot for determining the soil pH, electrical conductivity (EC), OC, available N, P, K and Zn. Processed samples were then stored in labelled and sealed polythene bags for chemical estimation. Soil pH (1 : 1, soil : water ratio) was determined by glass electrode while EC determined by Systronics electrical conductivity meter (27). Organic carbon was estimated by the rapid titration method (28), available N estimated by Modified Kjeldahl method (29), available P by Olsen's method (30), available K by Flame photometer method (27) and Zn by Atomic Absorption Spectrophotometric method (31).

### Statistical analysis

The experimental data were analysed by using Statistical Tool for Agricultural Research (STAR) software (version: 2.0.1). The significant difference between treatments was separated by using Tukey's honest significant difference (HSD) test at $p < 0.05$.

## 3. Results

### Nitrogen content and uptake

Nitrogen content and uptake were highly significant ($p < 0.001$) in sweet corn kernel and total N uptake (Table 1). The present study found highest N content (1.619 % to1.632 %) at 125 % RDF which proved significant superior than 75 % RDF only during both the years. However, 125 % RDF and 100 % RDF both the fertility levels failed to exert significant variation among them. Application of 100 % RDF recorded significantly higher total as well N uptake by sweet corn kernels during the first year while in second year it significantly enhanced up to the highest level of 125 % RDF. The N uptake by the cob husk, green fodder during both the years and total N uptake in first year significantly increased up to 100 % RDF only.

Nitrogen content in cob husk and nitrogen uptake by kernel, cob husk and total N uptake explicitly ($p < 0.001$) affected by mulch treatment. Application of rice straw mulch at 6 t $ha^{-1}$ led to significantly higher nitrogen content as well uptake compared to soil mulch in sweet corn, cob husk and green fodder during both the years of investigation. Total nitrogen uptake (12.65 %) was also higher by application of rice straw mulch.

Phosphorus levels influenced N content of sweet corn kernels and application of P at 130 kg $ha^{-1}$ (200 % RDP) proved significantly superior over its lower levels during first year at $p < 0.001$ and to 65 kg $ha^{-1}$ (100 % RDP) in second year, respectively. Regarding cob husk ($p < 0.001$) and green fodder significant increase in the N content found only up to 97.5 kg $ha^{-1}$ (150 % RDP) during both the years of experimentation. Application of various P levels proved significance ($p < 0.001$) for N uptake. Uptake of nitrogen by sweet corn, cob husk and total N uptake exhibited significant improvement up to the maximum level of 130 kg $P_2O_5$ $ha^{-1}$ except in total N uptake by green fodder during 2013 where significant effect seen up to 97.5 kg $P_2O_5$ $ha^{-1}$.

### Phosphorus content and uptake

The application of 125 % RDF showed distinct superiority over 75 % RDF in P content and uptake of sweet corn, cob husk and green fodder and total P uptake (Table 2). However, 125 % RDF and 100 % RDF failed to exert significant variation. Phosphorus uptake by kernel, cob husk (year 2013) and total uptake (year 2014) were significantly affected by RDF levels even at 0.1 % level of significance.

Rice straw mulch at 6 t $ha^{-1}$ caused significant variation and contained higher P in sweet corn, cob husk and green fodder than soil mulch during both the years of investigation. Similar trends of P total as well as individual uptake recorded in both years.

Phosphorus application at 130 kg $ha^{-1}$ claimed significantly more P content and uptake than 65 kg $ha^{-1}$ in sweet corn, cob husk and green fodder as well as total P uptake during both the years of experimentation. However, 130 kg $ha^{-1}$ and 97.5 kg $ha^{-1}$ were at par regarding P content. Phosphorus uptake by kernel in both years and total in second year were highly significant at $p < 0.001$.

### Potassium content and uptake

Data in Table 3 evinces that K content in green fodder and its uptake though various plant parts were significantly affected by treatment imposed even at $p < 0.001$ except kernel K uptake through RDF ($p < 0.01$).

Analysis of the data revealed that fertility levels caused marked improvement in K content of different plant parts. Application of 125 % RDF proved distinct superiority over 75 % RDF. However, 125 % RDF and 100 % RDF were non-significant during both the years. Application of 125 % RDF recorded significantly higher K uptake through various plant parts than 75 % RDF. Total K uptake and its portioning in cob husk and green fodder in 2014; were also significantly higher in 125 % RDF than 100 % RDF level.

Addition of rice straw mulch at 6 t $ha^{-1}$ caused lucid variation than soil mulch on K content and uptake of sweet corn. These parameters were significantly higher in straw as compared to soil mulch.

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**Table 1.** Effect of fertility level, mulch and phosphorus (P) levels on nitrogen (N) content (%) and uptake (kg ha$^{-1}$) by kernel, cob husk and green fodder of sweet corn (on dry weight basis)

| Treatment | N content (%) | | | | | | N uptake (kg ha$^{-1}$) | | | | | | Total N uptake (kg ha$^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Kernel | | Cob husk | | Green fodder | | Kernel | | Cob husk | | Green fodder | | | |
| | 2013 | 2014 | 2013 | 2014 | 2013 | 2014 | 2013 | 2014 | 2013 | 2014 | 2013 | 2014 | 2013 | 2014 |
| **Fertility levels** | | | | | | | | | | | | | | |
| $F_1$: 75 % RDF | 1.558$^{b}$ | 1.562$^{b}$ | 0.493$^{b}$ | 0.500$^{b}$ | 0.224$^{b}$ | 0.192$^{b}$ | 62.32$^{b}$ | 65.54$^{c}$ | 10.24$^{b}$ | 10.66$^{b}$ | 34.05$^{b}$ | 37.29$^{b}$ | 106.61$^{b}$ | 113.48$^{c}$ |
| $F_2$: 100 % RDF | 1.610$^{ab}$ | 1.613$^{a}$ | 0.522$^{ab}$ | 0.527$^{ab}$ | 0.254$^{ab}$ | 0.223$^{ab}$ | 68.81$^{a}$ | 72.04$^{b}$ | 11.63$^{a}$ | 11.96$^{a}$ | 40.45$^{ab}$ | 44.34$^{a}$ | 120.89$^{a}$ | 128.34$^{b}$ |
| $F_3$: 125 % RDF | 1.619$^{a}$ | 1.632$^{a}$ | 0.531$^{a}$ | 0.540$^{a}$ | 0.262$^{a}$ | 0.240$^{a}$ | 69.83$^{a}$ | 74.30$^{a}$ | 12.05$^{a}$ | 12.38$^{a}$ | 42.55$^{a}$ | 48.51$^{a}$ | 124.42$^{a}$ | 135.19$^{a}$ |
| **Mulch** | | | | | | | | | | | | | | |
| $M_1$: Soil Mulch | 1.588$^{b}$ | 1.589$^{b}$ | 0.488$^{b}$ | 0.495$^{b}$ | 0.228$^{b}$ | 0.202$^{b}$ | 63.82$^{b}$ | 67.57$^{b}$ | 10.32$^{b}$ | 10.63$^{b}$ | 34.83$^{b}$ | 39.42$^{b}$ | 108.97$^{b}$ | 117.62$^{a}$ |
| $M_2$:Straw Mulch | 1.603$^{a}$ | 1.616$^{a}$ | 0.543$^{a}$ | 0.550$^{a}$ | 0.266$^{a}$ | 0.234$^{a}$ | 70.15$^{a}$ | 73.69$^{a}$ | 12.30$^{a}$ | 12.70$^{a}$ | 43.20$^{a}$ | 47.34$^{a}$ | 125.64$^{a}$ | 133.72$^{b}$ |
| **Phosphorus levels** | | | | | | | | | | | | | | |
| $P_1$: 100 % RDP | 1.585$^{b}$ | 1.591$^{b}$ | 0.501$^{b}$ | 0.506$^{b}$ | 0.223$^{b}$ | 0.191$^{b}$ | 64.39$^{c}$ | 66.39$^{c}$ | 10.51$^{b}$ | 10.84$^{c}$ | 33.95$^{b}$ | 37.23$^{b}$ | 108.85$^{c}$ | 114.47$^{c}$ |
| $P_2$: 150 % RDP | 1.590$^{b}$ | 1.601$^{ab}$ | 0.519$^{a}$ | 0.525$^{a}$ | 0.250$^{ab}$ | 0.218$^{ab}$ | 67.00$^{b}$ | 71.58$^{b}$ | 11.43$^{b}$ | 11.74$^{b}$ | 39.66$^{a}$ | 43.27$^{ab}$ | 118.10$^{b}$ | 126.59$^{b}$ |
| $P_3$: 200 % RDP | 1.612$^{a}$ | 1.615$^{a}$ | 0.526$^{a}$ | 0.535$^{a}$ | 0.267$^{a}$ | 0.245$^{a}$ | 69.56$^{a}$ | 73.90$^{a}$ | 11.98$^{a}$ | 12.41$^{a}$ | 43.43$^{a}$ | 49.64$^{a}$ | 124.98$^{a}$ | 135.95$^{a}$ |
| **F values** | | | | | | | | | | | | | | |
| RDF | 63.65$^{***}$ | 32.10$^{***}$ | 4.44* | 4.27$^{*}$ | 5.17$^{*}$ | 6.23$^{*}$ | 36.17$^{***}$ | 62.12$^{***}$ | 14.36$^{**}$ | 13.19$^{**}$ | 7.09$^{*}$ | 8.10$^{**}$ | 34.62$^{***}$ | 30.33$^{***}$ |
| Mulch | 9.46$^{*}$ | 12.94$^{**}$ | 24.70$^{***}$ | 23.26$^{***}$ | 13.71$^{**}$ | 8.14$^{*}$ | 65.53$^{***}$ | 84.08$^{***}$ | 47.03$^{***}$ | 52.51$^{***}$ | 19.03$^{**}$ | 11.86$^{**}$ | 81.20$^{***}$ | 47.90$^{***}$ |
| RDP | 9.95$^{***}$ | 7.95$^{*}$ | 13.83$^{***}$ | 20.17$^{***}$ | 7.89$^{**}$ | 7.64$^{**}$ | 18.10$^{***}$ | 36.88$^{***}$ | 19.43$^{***}$ | 26.00$^{***}$ | 10.19$^{***}$ | 10.12$^{***}$ | 24.96$^{***}$ | 27.56$^{***}$ |
| RDF × Mulch | 7.72$^{ns}$ | 5.64$^{ns}$ | 5.16$^{ns}$ | 5.30$^{ns}$ | 2.16$^{ns}$ | 4.32$^{ns}$ | 9.30$^{ns}$ | 21.02$^{ns}$ | 4.91$^{ns}$ | 6.71$^{ns}$ | 2.66$^{ns}$ | 4.63$^{ns}$ | 10.92$^{ns}$ | 14.47$^{ns}$ |
| Mulch × RDP | 1.66$^{ns}$ | 5.42$^{ns}$ | 3.93$^{ns}$ | 3.55$^{ns}$ | 0.77$^{ns}$ | 0.61$^{ns}$ | 2.06$^{ns}$ | 8.49$^{ns}$ | 2.23$^{ns}$ | 2.43$^{ns}$ | 0.72$^{ns}$ | 0.67$^{ns}$ | 0.11$^{ns}$ | 1.45$^{ns}$ |
| RDF × RDP | 0.98$^{ns}$ | 1.49$^{ns}$ | 6.17$^{ns}$ | 3.51$^{ns}$ | 0.13$^{ns}$ | 0.20$^{ns}$ | 3.25$^{ns}$ | 2.48$^{ns}$ | 1.37$^{ns}$ | 0.95$^{ns}$ | 0.07$^{ns}$ | 0.13$^{ns}$ | 0.31$^{ns}$ | 0.66$^{ns}$ |
| RDF × Mulch × RDP | 1.27$^{ns}$ | 7.60$^{ns}$ | 3.50$^{ns}$ | 8.48$^{ns}$ | 1.22$^{ns}$ | 0.28$^{ns}$ | 3.33$^{ns}$ | 2.94$^{ns}$ | 2.74$^{ns}$ | 3.81$^{ns}$ | 1.24$^{ns}$ | 0.30$^{ns}$ | 3.22$^{ns}$ | 0.74$^{ns}$ |

RDF: recommended dose of fertiliser; RDP: recommended dose of phosphorus; ns: non-significant. *Significant at $p \leq 0.05$; **significant at $p \leq 0.01$; ***significant at $p \leq 0.001$. Means with different letters within a column are significantly different at $p \leq 0.05$ according to Tukey's test.

**Table 2.** Effect of fertility, mulch and phosphorus levels on phosphorus (P) content (%) and uptake (kg ha$^{-1}$) by kernel, cob husk and green fodder of sweet corn (on dry weight basis)

| Treatment | P content (%) | | | | | | P uptake (kg ha$^{-1}$) | | | | | | Total P uptake (kg ha$^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Kernel | | Cob husk | | Green fodder | | Kernel | | Cob husk | | Green fodder | | | |
| | 2013 | 2014 | 2013 | 2014 | 2013 | 2014 | 2013 | 2014 | 2013 | 2014 | 2013 | 2014 | 2013 | 2014 |
| **Fertility levels** | | | | | | | | | | | | | | |
| $F_1$: 75 % RDF | 0.214$^{b}$ | 0.218$^{b}$ | 0.104$^{b}$ | 0.121$^{b}$ | 0.059$^{b}$ | 0.063$^{b}$ | 8.65$^{b}$ | 9.23$^{b}$ | 2.17$^{b}$ | 2.59$^{b}$ | 10.94$^{b}$ | 12.36$^{b}$ | 21.76$^{b}$ | 24.18$^{b}$ |
| $F_2$: 100 % RDF | 0.230$^{ab}$ | 0.233$^{ab}$ | 0.117$^{ab}$ | 0.132$^{ab}$ | 0.072$^{ab}$ | 0.086$^{a}$ | 9.85$^{a}$ | 10.45$^{a}$ | 2.60$^{a}$ | 2.98$^{a}$ | 13.55$^{ab}$ | 17.16$^{a}$ | 26.00$^{a}$ | 30.60$^{a}$ |
| $F_3$: 125 % RDF | 0.240$^{a}$ | 0.246$^{a}$ | 0.129$^{a}$ | 0.144$^{a}$ | 0.081$^{a}$ | 0.094$^{a}$ | 10.37$^{a}$ | 11.21$^{a}$ | 2.94$^{a}$ | 3.30$^{a}$ | 15.55$^{a}$ | 19.00$^{a}$ | 28.85$^{a}$ | 33.51$^{a}$ |
| **Mulch** | | | | | | | | | | | | | | |
| $M_1$: Soil Mulch | 0.218$^{b}$ | 0.221$^{b}$ | 0.110$^{b}$ | 0.124$^{b}$ | 0.063$^{b}$ | 0.071$^{b}$ | 8.82$^{b}$ | 9.47$^{b}$ | 2.32$^{b}$ | 2.68$^{b}$ | 11.74$^{b}$ | 13.98$^{b}$ | 22.88$^{b}$ | 26.12$^{b}$ |
| $M_2$: Straw Mulch | 0.238$^{a}$ | 0.244$^{a}$ | 0.124$^{a}$ | 0.140$^{a}$ | 0.078$^{a}$ | 0.091$^{a}$ | 10.43$^{a}$ | 11.12$^{a}$ | 2.82$^{a}$ | 3.24$^{a}$ | 14.94$^{a}$ | 18.37$^{a}$ | 28.19$^{a}$ | 32.73$^{a}$ |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Phosphorus levels** | | | | | | | | | | | | | | |
| $P_1$: 100 % RDP | 0.217$^{b}$ | 0.222$^{b}$ | 0.108$^{b}$ | 0.123$^{b}$ | 0.062$^{b}$ | 0.071$^{b}$ | 8.86$^{b}$ | 9.29$^{b}$ | 2.27$^{b}$ | 2.64$^{b}$ | 11.54$^{b}$ | 13.78$^{b}$ | 22.68$^{b}$ | 25.71$^{b}$ |
| $P_2$: 150 % RDP | 0.230$^{ab}$ | 0.233$^{ab}$ | 0.117$^{ab}$ | 0.132$^{ab}$ | 0.072$^{ab}$ | 0.083$^{ab}$ | 9.75$^{a}$ | 10.48$^{a}$ | 2.58$^{ab}$ | 2.95$^{ab}$ | 13.61$^{ab}$ | 16.61$^{a}$ b | 25.94$^{a}$ | 30.04$^{a}$ |
| $P_3$: 200 % RDP | 0.237$^{a}$ | 0.242$^{a}$ | 0.126$^{a}$ | 0.142$^{a}$ | 0.078$^{a}$ | 0.089$^{a}$ | 10.25$^{a}$ | 11.11$^{a}$ | 2.86$^{a}$ | 3.28$^{a}$ | 14.88$^{a}$ | 18.14$^{a}$ | 27.99$^{a}$ | 32.53$^{a}$ |
| ***F* values** | | | | | | | | | | | | | | |
| RDF | 9.4$^{**}$ | 9.09$^{**}$ | 8.86$^{**}$ | 6.6$^{*}$ | 4.57$^{*}$ | 8.51$^{**}$ | 21.92$^{***}$ | 22.92$^{***}$ | 17.22$^{**}$ * | 13.14$^{*}$ * | 5.48$^{*}$ | 10.60$^{*}$ * | 12.81$^{**}$ | 18.37$^{***}$ |
| Mulch | 17.12$^{**}$ | 17.75$^{**}$ | 8.87$^{*}$ | 10.11$^{**}$ | 6.35$^{*}$ | 9.39$^{*}$ | 54.91$^{***}$ | 46.74$^{***}$ | 21.47$^{**}$ * | 24.28$^{*}$ ** | 7.88$^{*}$ | 13.07$^{*}$ * | 21.24$^{**}$ | 26.38$^{***}$ |
| RDP | 6.46$^{**}$ | 7.9$^{**}$ | 3.57$^{*}$ | 3.62$^{*}$ | 3.71$^{*}$ | 3.81$^{*}$ | 12.72$^{***}$ | 20.93$^{***}$ | 8.42$^{**}$ | 9.01$^{**}$ | 4.48$^{*}$ | 4.64$^{*}$ | 9.09$^{**}$ | 9.90$^{***}$ |
| RDF × Mulch | 2.06 $^{ns}$ | 1.66 $^{ns}$ | 0.37 $^{ns}$ | 1.57 $^{ns}$ | 0.73 $^{ns}$ | 0.86 $^{ns}$ | 9.71 $^{ns}$ | 10.82 ns | 0.48 $^{ns}$ | 2.07 $^{ns}$ | 0.80 $^{ns}$ | 1.02 $^{ns}$ | 2.35 $^{ns}$ | 2.81 $^{ns}$ |
| Mulch × RDP | 1.26 $^{ns}$ | 1.45 $^{ns}$ | 0.46 $^{ns}$ | 0.81 $^{ns}$ | 0.18 $^{ns}$ | 0.27 $^{ns}$ | 0.53 $^{ns}$ | 1.00 $^{ns}$ | 0.69 $^{ns}$ | 0.81 $^{ns}$ | 0.15 $^{ns}$ | 0.23 $^{ns}$ | 0.08 $^{ns}$ | 0.19 $^{ns}$ |
| RDF × RDP | 0.04 $^{ns}$ | 0.29 $^{ns}$ | 0.18 $^{ns}$ | 2.31 $^{ns}$ | 0.49 $^{ns}$ | 0.18 $^{ns}$ | 0.87 $^{ns}$ | 0.84 $^{ns}$ | 0.19 $^{ns}$ | 2.48 $^{ns}$ | 0.50 $^{ns}$ | 0.12 $^{ns}$ | 0.67 $^{ns}$ | 0.36 $^{ns}$ |
| RDF × Mulch × RDP | 0.83 $^{ns}$ | 1.11 $^{ns}$ | 0.97 $^{ns}$ | 0.97 $^{ns}$ | 1.00 $^{ns}$ | 0.96 $^{ns}$ | 2.15 $^{ns}$ | 1.45 $^{ns}$ | 1.12 $^{ns}$ | 0.81 $^{ns}$ | 0.99 $^{ns}$ | 0.91 $^{ns}$ | 1.52 $^{ns}$ | 0.85 ns |

RDF: recommended dose of fertiliser; RDP: recommended dose of phosphorus; ns: non-significant. *Significant at $p \leq 0.05$; **significant at $p \leq 0.01$; ***significant at $p \leq 0.001$. Means with different letters within a column are significantly different at $p \leq 0.05$ according to Tukey's test.

**Table 3.** Effect of fertility, mulch and phosphorus levels on potassium (K) content (%) and uptake (kg ha$^{-1}$) by kernel, cob husk and green fodder of sweet corn (on dry weight basis)

| Treatment | K content (%) | | | | | | K uptake (kg ha$^{-1}$) | | | | | | Total K uptake (kg ha$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Kernel | | Cob husk | | Green fodder | | Kernel | | Cob husk | | Green fodder | | | | |
| | 2013 | 2014 | 2013 | 2014 | 2013 | 2014 | 2013 | 2014 | 2013 | 2014 | 2013 | 2014 | 2014 | 2013 | 2014 |
| **Fertility levels** | | | | | | | | | | | | | | | |
| $F_1$: 75 % RDF | 0.139$^{b}$ | 0.152$^{b}$ | 0.199$^{b}$ | 0.206$^{b}$ | 0.227$^{b}$ | 0.236$^{b}$ | 5.67$^{b}$ | 6.48$^{b}$ | 4.16$^{b}$ | 4.41$^{c}$ | 41.89$^{b}$ | 45.92$^{c}$ | 51.73$^{c}$ | 56.80$^{c}$ | |
| $F_2$: 100 % RDF | 0.166$^{ab}$ | 0.173$^{ab}$ | 0.224$^{a}$ | 0.233$^{a}$ | 0.284$^{a}$ | 0.300$^{a}$ | 7.16$^{a}$ | 7.83$^{ab}$ | 4.99$^{a}$ | 5.29$^{b}$ | 53.66$^{ab}$ | 59.70$^{b}$ | 65.81$^{b}$ | 72.82$^{b}$ | |
| $F_3$: 125 % RDF | 0.184$^{a}$ | 0.191$^{a}$ | 0.232$^{a}$ | 0.250$^{a}$ | 0.299$^{a}$ | 0.317$^{a}$ | 7.97$^{a}$ | 8.74$^{a}$ | 5.25$^{a}$ | 5.72$^{a}$ | 57.30$^{a}$ | 63.97$^{a}$ | 70.52$^{a}$ | 78.43$^{a}$ | |
| **Mulch** | | | | | | | | | | | | | | | |
| $M_1$: Soil Mulch | 0.143$^{b}$ | 0.148$^{b}$ | 0.205$^{b}$ | 0.212$^{b}$ | 0.239$^{b}$ | 0.261$^{b}$ | 5.83$^{b}$ | 6.42$^{b}$ | 4.35$^{b}$ | 4.58$^{b}$ | 44.33$^{b}$ | 50.93$^{b}$ | 54.51$^{b}$ | 61.92$^{b}$ | |
| $M_2$: Straw Mulch | 0.184$^{a}$ | 0.196$^{a}$ | 0.232$^{a}$ | 0.247$^{a}$ | 0.301$^{a}$ | 0.307$^{a}$ | 8.04$^{a}$ | 8.95$^{a}$ | 5.25$^{a}$ | 5.70$^{a}$ | 57.57$^{a}$ | 62.13$^{a}$ | 70.87$^{a}$ | 76.78$^{a}$ | |
| **Phosphorus levels** | | | | | | | | | | | | | | | |
| $P_1$: 100 % RDP | 0.138$^{b}$ | 0.144$^{b}$ | 0.207$^{b}$ | 0.215$^{b}$ | 0.247$^{c}$ | 0.259$^{c}$ | 5.66$^{b}$ | 6.07$^{b}$ | 4.37$^{c}$ | 4.63$^{c}$ | 45.72$^{c}$ | 50.42$^{c}$ | 55.75$^{c}$ | 61.12$^{c}$ | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $P_2$: 150 % RDP | 0.169$^{a}$ | 0.178$^{a}$ | 0.217$^{ab}$ | 0.229$^{ab}$ | 0.271$^{b}$ | 0.292$^{b}$ | 7.18$^{a}$ | 8.05$^{a}$ | 4.78$^{b}$ | 5.12$^{b}$ | 51.23$^{b}$ | 57.96$^{b}$ | 63.19$^{b}$ | 71.14$^{b}$ |
| $P_3$: 200 % RDP | 0.184$^{a}$ | 0.193$^{a}$ | 0.231$^{a}$ | 0.244$^{a}$ | 0.292$^{a}$ | 0.302$^{a}$ | 7.96$^{a}$ | 8.92$^{a}$ | 5.26$^{a}$ | 5.67$^{a}$ | 55.90$^{a}$ | 61.21$^{a}$ | 69.12$^{a}$ | 75.80$^{a}$ |
| | | | | | | | ***F* values** | | | | | | | |
| RDF | 8.27$^{**}$ | 4.68$^{*}$ | 7.15$^{*}$ | 21.7$^{***}$ | 36.12$^{***}$ | 60.69$^{***}$ | 14.33$^{**}$ | 8.86$^{**}$ | 15.69$^{**}$ | 31.70$^{***}$ | 45.43$^{***}$ | 77.16$^{**}$ | 51.80$^{*}$ | 119.77$^{***}$ |
| Mulch | 20.59$^{**}$ | 20.61$^{**}$ | 13.5$^{**}$ | 40.04$^{**}$ | 70.12$^{***}$ | 53.95$^{***}$ | 38.92$^{***}$ | 32.58$^{***}$ | 29.99$^{**}$ | 67.87$^{***}$ | 92.06$^{***}$ | 81.68$^{**}$ | 108.76$^{***}$ | 157.55$^{***}$ |
| RDP | 11.65$^{***}$ | 8.92$^{**}$ | 5.24$^{*}$ | 9.26$^{**}$ | 11.03$^{***}$ | 28.69$^{***}$ | 15.61$^{***}$ | 13.67$^{***}$ | 13.58$^{**}$ | 20.35$^{***}$ | 14.65$^{***}$ | 43.63$^{**}$ | 21.84$^{*}$ | 68.69$^{**}$ |
| RDF × Mulch | 1.01$^{ns}$ | 1.04$^{ns}$ | 3.70$^{ns}$ | 3.92$^{ns}$ | 7.80$^{ns}$ | 3.71$^{ns}$ | 2.59$^{ns}$ | 3.37$^{ns}$ | 6.78$^{ns}$ | 4.12$^{ns}$ | 10.57$^{ns}$ | 4.94$^{ns}$ | 5.16$^{ns}$ | 10.28$^{ns}$ |
| Mulch × RDP | 0.28$^{ns}$ | 0.21$^{ns}$ | 1.58$^{ns}$ | 0.96$^{ns}$ | 1.00$^{ns}$ | 2.21$^{ns}$ | 0.46$^{ns}$ | 0.49$^{ns}$ | 1.66$^{ns}$ | 0.91$^{ns}$ | 0.97$^{ns}$ | 1.73$^{ns}$ | 1.12$^{ns}$ | 1.35$^{ns}$ |
| RDF × RDP | 0.86$^{ns}$ | 1.04$^{ns}$ | 3.60$^{ns}$ | 1.16$^{ns}$ | 5.38$^{ns}$ | 2.54$^{ns}$ | 1.49$^{ns}$ | 0.89$^{ns}$ | 2.94$^{ns}$ | 0.86$^{ns}$ | 4.39$^{ns}$ | 2.22$^{ns}$ | 3.02$^{ns}$ | 2.75$^{ns}$ |
| RDF ×Mulch × RDP | 0.41$^{ns}$ | 0.17$^{ns}$ | 1.71$^{ns}$ | 2.53$^{ns}$ | 4.49$^{ns}$ | 6.56$^{ns}$ | 0.17$^{ns}$ | 0.22$^{ns}$ | 1.19$^{ns}$ | 1.85$^{ns}$ | 4.23$^{ns}$ | 6.18$^{ns}$ | 3.76$^{ns}$ | 5.33$^{ns}$ |

RDF: recommended dose of fertiliser; RDP: recommended dose of phosphorus; ns: non-significant. *Significant at $p \leq 0.05$; **significant at $p \leq 0.01$; ***significant at $p \leq 0.001$. Means with different letters within a column are significantly different at $p \leq 0.05$ according to Tukey's test.

Potassium content and uptake of sweet corn kernel, cob husk and green fodder improved significantly with application of P at 130 kg ha$^{-1}$ over 65 kg ha$^{-1}$. Application of 97.5 kg $P_2O_5$ ha$^{-1}$ resulted in comparable K content with 130 kg ha$^{-1}$ in various plant parts, except in green fodder, where it was significantly lower, indicating that reproductive and structural tissues reach K saturation at a lower P threshold than vegetative tissue, which continues to respond due to its greater sink capacity and longer accumulation period. Potassium uptake in various plant parts enhanced significantly with advancement of $P_2O_5$ levels up to 200 %, except in sweet corn kernel, where it enhanced only up to 150 %, suggesting that kernel K demand is fixed by its developmental sink strength and is met at a comparatively lower P supply, beyond which additional P does not translate into further K accumulation in this tissue.

**Zinc content and uptake**

Various RDF levels significantly affected ($p < 0.001$) Zn content and uptake (Table 4), reflecting the coupling between macronutrient supply and Zn assimilation. Zn content increased up to 125 % RDF in kernel and 2014 green fodder, likely due to improved root proliferation and $Zn^{2+}$ carrier activity under enhanced NPK availability, whereas cob husk and 2013 green fodder plateaued at 100 % RDF, indicating earlier attainment of tissue-specific Zn saturation and preferential partitioning toward reproductive sinks at higher fertility. Zn uptake followed a parallel trend, rising to 125 % RDF in green fodder and total uptake (2.56-11.18 %), but plateauing at 100 % RDF in cob husk, consistent with uptake being co-determined by biomass accumulation rather than tissue Zn concentration alone.

Zinc uptake and content in various plant parts as affected by mulching were significant even at $p < 0.001$. Significantly higher Zn content and uptake observed with rice straw mulch application at 6 t ha$^{-1}$ over soil.

The present study found an inverse relationship was there between in $P_2O_5$ application and Zn content. Increasing levels of P from 65 to 130 kg ha$^{-1}$ significantly reduced Zn content (1.5 % to 2.7 %) of sweet corn, cob husk and green fodder during both the years. Data indicated that increasing levels of P application up to 97.5 kg ha$^{-1}$ significantly enhanced uptake of Zn by sweet corn, cob husk, green fodder and total Zn uptake over 65 kg P ha$^{-1}$ during both the years (except cob husk in 2014). However, Zn uptake in various plant parts at 97.5 and 130 kg P ha$^{-1}$ remained statistically at par.

**Effect on soil properties**

Soil properties like OC, pH and EC were not significantly influenced by any of the treatment imposed over two-year experimentation. Variation in RDF and RDP had high impact ($p < 0.001$) on nutrient availability after harvesting of the crop. However, soil available N and K were keenly varied ($p < 0.001$) due to mulch compared to the P and Zn ($p < 0.05$).

Status of soil available nutrients viz. N, P and K found to be significantly enhanced with each successive increment in RDF level up to 125 %. However, Zn availability was significantly enhanced up to the 100 % RDF only. Soil N and Zn were apparently lost more by $F_3$ (Fig. 2) however K was gained.

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**Table 4.** Effect of fertility, mulch and phosphorus levels on zinc (Zn) content (mg kg$^{-1}$) and uptake (kg ha$^{-1}$) by kernel, cob husk and green fodder of sweet corn (on dry weight basis)

| Treatment | Zn content (mg kg$^{-1}$) | | | | | | Zn uptake (kg ha$^{-1}$) | | | | | | Total Zn uptake (kg ha$^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Kernel | | Cob husk | | Green fodder | | Kernel | | Cob husk | | Green fodder | | | |
| | 2013 | 2014 | 2013 | 2014 | 2013 | 2014 | 2013 | 2014 | 2013 | 2014 | 2013 | 2014 | 2013 | 2014 |
| **Fertility levels** | | | | | | | | | | | | | | |
| $F_1$: 75 % RDF | 29.301$^{c}$ | 29.584$^{c}$ | 36.164$^{b}$ | 36.220$^{b}$ | 51.088$^{b}$ | 51.253$^{c}$ | 0.117$^{b}$ | 0.124$^{c}$ | 0.075$^{b}$ | 0.077$^{b}$ | 0.942$^{c}$ | 0.992$^{c}$ | 1.134$^{c}$ | 1.193$^{c}$ |
| $F_2$: 100 % RDF | 29.889$^{b}$ | 29.946$^{b}$ | 37.033$^{a}$ | 37.124$^{a}$ | 51.758$^{a}$ | 51.923$^{b}$ | 0.128$^{a}$ | 0.134$^{b}$ | 0.082$^{a}$ | 0.084$^{a}$ | 0.975$^{b}$ | 1.031$^{b}$ | 1.185$^{b}$ | 1.249$^{b}$ |
| $F_3$: 125 % RDF | 30.250$^{a}$ | 30.449$^{a}$ | 37.139$^{a}$ | 37.288$^{a}$ | 51.974$^{a}$ | 52.079$^{a}$ | 0.130$^{a}$ | 0.139$^{a}$ | 0.084$^{a}$ | 0.085$^{a}$ | 0.994$^{a}$ | 1.051$^{a}$ | 1.209$^{a}$ | 1.275$^{a}$ |
| **Mulch** | | | | | | | | | | | | | | |
| $M_1$: Soil Mulch | 29.509$^{b}$ | 29.415$^{b}$ | 36.384$^{b}$ | 36.443$^{b}$ | 51.081$^{b}$ | 51.211$^{b}$ | 0.119$^{b}$ | 0.125$^{b}$ | 0.077$^{b}$ | 0.078$^{b}$ | 0.944$^{b}$ | 0.994$^{b}$ | 1.140$^{b}$ | 1.197$^{b}$ |
| $M_2$: Straw Mulch | 30.118$^{a}$ | 30.571$^{a}$ | 37.174$^{a}$ | 37.311$^{a}$ | 52.133$^{a}$ | 52.292$^{a}$ | 0.132$^{a}$ | 0.139$^{a}$ | 0.084$^{a}$ | 0.086$^{a}$ | 0.996$^{a}$ | 1.055$^{a}$ | 1.212$^{a}$ | 1.281$^{a}$ |
| **Phosphorus levels** | | | | | | | | | | | | | | |
| $P_1$: 100 % RDP | 30.127$^{a}$ | 30.440$^{a}$ | 37.200$^{a}$ | 37.252$^{a}$ | 51.903$^{a}$ | 52.121$^{a}$ | 0.122$^{b}$ | 0.127$^{b}$ | 0.078$^{b}$ | 0.079$^{b}$ | 0.957$^{b}$ | 1.011$^{b}$ | 1.157$^{b}$ | 1.217$^{b}$ |
| $P_2$: 150 % RDP | 29.762$^{b}$ | 29.900$^{b}$ | 36.936$^{b}$ | 37.086$^{a}$ | 51.784$^{a}$ | 51.920$^{a}$ | 0.126$^{a}$ | 0.134$^{a}$ | 0.081$^{a}$ | 0.083$^{ab}$ | 0.977$^{a}$ | 1.028$^{a}$ | 1.184$^{a}$ | 1.245$^{a}$ |
| $P_3$: 200 % RDP | 29.551$^{c}$ | 29.639$^{c}$ | 36.201$^{c}$ | 36.293$^{b}$ | 51.134$^{b}$ | 51.214$^{b}$ | 0.127$^{a}$ | 0.136$^{a}$ | 0.082$^{a}$ | 0.084$^{a}$ | 0.976$^{a}$ | 1.034$^{a}$ | 1.186$^{a}$ | 1.254$^{a}$ |
| ***F* values** | | | | | | | | | | | | | | |
| RDF | 29.35$^{***}$ | 35.98$^{***}$ | 59.39$^{***}$ | 75.9$^{***}$ | 27.37$^{***}$ | 28.32$^{***}$ | 20.97$^{**}$ | 57.83$^{***}$ | 15.38$^{***}$ | 29.14$^{***}$ | 56.97$^{***}$ | 30.77$^{***}$ | 95.16$^{***}$ | 51.78$^{***}$ |
| Mulch | 35.57$^{***}$ | 190.69$^{**}$ | 97.13$^{***}$ | 129.4$^{***}$ | 106.54$^{**}$ | 128.91$^{**}$ | 67.23$^{**}$ | 136.23$^{**}$ | 45.66$^{***}$ | 62.24$^{***}$ | 155.08$^{*}$ | 96.04$^{***}$ | 256.38$^{***}$ | 155.77$^{**}$ |
| RDP | 65.62$^{***}$ | 75.41$^{***}$ | 78.5$^{***}$ | 64.35$^{***}$ | 31.29$^{***}$ | 46.5$^{***}$ | 6.28$^{**}$ | 28.93$^{***}$ | 6.28$^{**}$ | 3.71$^{*}$ | 5.32$^{*}$ | 6.38$^{**}$ | 12.09$^{***}$ | 17.60$^{***}$ |
| RDF × Mulch | 14.51$^{ns}$ | 48.93$^{ns}$ | 28.61$^{ns}$ | 28.25$^{ns}$ | 4.53$^{ns}$ | 4.20$^{ns}$ | 4.16$^{ns}$ | 16.89$^{ns}$ | 2.92$^{ns}$ | 3.28$^{ns}$ | 4.76$^{ns}$ | 4.48$^{ns}$ | 5.75$^{ns}$ | 3.99$^{ns}$ |
| Mulch × RDP | 7.28$^{ns}$ | 6.81$^{ns}$ | 2.89$^{ns}$ | 2.42$^{ns}$ | 0.34$^{ns}$ | 0.70$^{ns}$ | 0.28$^{ns}$ | 11.33$^{ns}$ | 0.90$^{ns}$ | 1.04$^{ns}$ | 0.34$^{ns}$ | 1.31$^{ns}$ | 0.14$^{ns}$ | 2.31$^{ns}$ |
| RDF × RDP | 0.52$^{ns}$ | 3.54$^{ns}$ | 29.46$^{ns}$ | 31.63$^{ns}$ | 1.52$^{ns}$ | 2.36$^{ns}$ | 6.69$^{ns}$ | 6.53$^{ns}$ | 0.90$^{ns}$ | 0.29$^{ns}$ | 4.10$^{ns}$ | 0.22$^{ns}$ | 6.44$^{ns}$ | 0.54$^{ns}$ |
| RDF × Mulch × RDP | 1.21$^{ns}$ | 4.59$^{ns}$ | 2.88$^{ns}$ | 1.54$^{ns}$ | 0.72$^{ns}$ | 0.09$^{ns}$ | 4.00$^{ns}$ | 6.93$^{ns}$ | 0.07$^{ns}$ | 0.61$^{ns}$ | 1.26$^{ns}$ | 1.09$^{ns}$ | 1.70$^{ns}$ | 1.02$^{ns}$ |

RDF: recommended dose of fertiliser; RDP: recommended dose of phosphorus; ns: non-significant. *Significant at $p \leq 0.05$; **significant at $p \leq 0.01$; ***significant at $p \leq 0.001$. Means with different letters within a column are significantly different at $p \leq 0.05$ according to Tukey's test.

Rice straw mulch application caused an increase in the amount of available nutrients than soil mulch and the differences were significant during both the years. However, P and Zn availability significantly enhanced at $p < 0.05$.

Increasing levels of P application significantly enhanced the available (12–15 % N, 28–30 % $P_2O_5$ and 7–8 % $K_2O$ to the maximum level of 130 kg P ha$^{-1}$. As the levels of P application increased Zn availability decreased and 100 % RDP claimed significantly highest Zn than 200 % RDP during both the years. Higher negative P balance was recorded with $P_3$.

## Discussion

The study evaluated the effects of fertility levels and mulching on nutrient content and uptake in sweet corn and the results revealed significant treatment effects across various plant parts. Application of 125 % RDF achieved distinct superiority over 75 % RDF in nutrient content and uptake, but remained statistically at par with 100 % RDF, indicating that nutrient assimilation had largely plateaued beyond the 100 % RDF level. This response can be attributed to the assured and adequate supply of N, K and Zn under higher fertilisation, coupled with positive synergistic interactions among N × K, K × P, N × P and N × Zn, which enhance nutrient absorption and translocation efficiency in plant tissues (31, 32).

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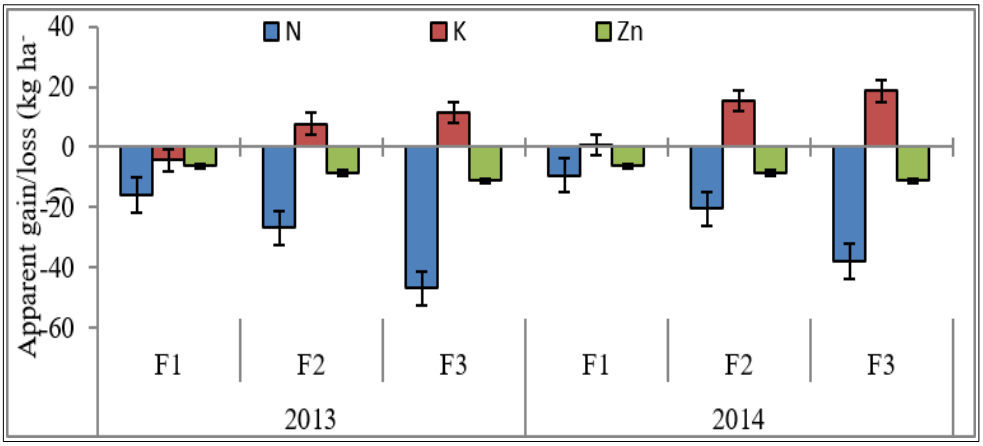



**Fig. 2.** Effect of fertility levels on apparent gain/loss of soil available nitrogen, potassium and zinc.
Error bars represent ± standard error of means.

The general nutrient content pattern of N and P was sweet corn kernel > cob husk > green fodder while; it was reverse in term of K and Zn. Nitrogen and P are the major component of amino acids, protein, nucleic acid and DNA present in kernel thus found more luxuriant. Potassium promotes photosynthetic activity, translocation, flow and storage of assimilates in plant system. Zinc plays a significant role in various enzymatic and physiological activities and performs many catalytic functions in plants besides transformation of carbohydrates, chlorophyll, N metabolism and protein synthesis (33) thus found more in green fodder.

On the other hand, uptake of all nutrients (except N) observed higher by green fodder than kernels and cob husk. Nutrient uptake is the product of content and plant dry matter. Higher N content in kernel and along with good yield resulted higher N uptake than green fodder and cob husk which is also applicable in case of other nutrient to ascertain higher uptake through green fodder. Moderate fertility levels (150.0 kg N + 65.0 kg $K_2O$ + 10.0 kg Zn $ha^{-1}$) assured the constant availability of nutrients to crops in adequate amounts. Hence, 100 % RDF produced equally vigorous plants as 125 % RDF as witnessed by taller plant height, more no. of active leaves, higher leaf area index and dry matter content recorded in our study (data not presented). More vigorous plants contained higher concentration ascertained greater uptake of nutrients by sweet corn, cob husk and green fodder. Results match with the findings of (34–36). Similarly, previous researchers found that application of 150 kg N $ha^{-1}$ (as also in present treatments at $F_2$) resulted significantly higher nutrient content and yields thus nitrogen phosphorus and potassium uptake by maize than lower dosages (37).

The general hypothesis is that straw mulch in short growing sweet crop will not significantly affect the nutrient uptake pattern and soil nutrient status after harvesting in rainfed conditions. Rather, we found a significant effect ($p < 0.001$) especially on N content in cob husk; K content in green fodder and Zn content in various plant parts which constitutes novelty of this paper. Nutrient content in various plant parts was higher especially K in kernel ($p < 0.01$) with tune of 28–34 % and in green fodder 17–21 % increment over soil mulch. Nitrogen and P were more in sweet corn than cob husk and green fodder while K and Zn were in reverse trend. Mulch provided a better soil environment, water infiltration rate along with satisfactorily rainfall, moderate temperatures (Fig. 1) and moisture retention in soil and reduced the evaporation thus, probably enhanced microbial activity and nutrient transformation with assured supply of nutrients due to treatments which resultant better plant growth. Previous studies evaluated the effectiveness of organic mulch on the productivity of maize and concluded that highest soil moisture reserves, least weed infestation obtained at 6 or 8 t $ha^{-1}$ (38). Vigorous plants along with higher nutrient content ascertained greater uptake of nutrients by sweet corn, cob husk and green fodder thereby total nutrient uptake. Higher quantity of available N, P and K in the soil due to the favorable micro climate through straw mulching under rainfed condition was also contributed (Table 5). Some of researchers found such type of findings (39, 40).

Application of P at increase rates (130 kg $P_2O_5$ $ha^{-1}$) than recommended enhanced its availability in the rhizospheric zone and thus increased the availability for the plants. Phosphorus is known to have very low use efficiency thus improvement in application rates probably enhanced the nutrient acquisition by plants and their translocation especially of N, P and K to different plant parts viz. sweet corn, cob husk and green fodder and thereby increased concentration of such nutrients resulting into their higher content and uptake. Increase in levels of P application from 65 to 130 kg $P_2O_5$ $ha^{-1}$ exerted lucid variation on N, P, K and Zn content and their uptake by sweet corn, cob husk and green fodder during both the years of investigation (Tables 1–4). However, P levels increased N, K content and K uptake by sweet corn, cob husk and green fodder significantly up to 97.5 kg $P_2O_5$ $ha^{-1}$ and thereafter the increases were not significant. It was interesting to note that increase in the P levels significantly decreased Zn content and least were recorded at 130 kg $P_2O_5$ $ha^{-1}$ while total Zn uptake as well by sweet corn, cob husk

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and green fodder was higher at $P_2$ and $P_3$. This could be ascribed to the favourable effect of P application on growth attributes especially dry matter content (data not presented) along with good Zn content. Similar results have also been reported in maize by (41–43). Reduction in Zn content with the increase in the levels of P might be attributed to the effect of the interaction between Zn and P in soil and plant. If one of these nutrients is applied at a higher rate probably it affects the availability of the other. It is possible that at 200 % RDP (130 kg $P_2O_5$ $ha^{-1}$), the higher levels of P in soil reduced Zn availability in soil as showed in Table 5. Previous studies suggested P-Zn antagonism in rhyzosphere (44, 45). Increased crop growth due to P nutrition significantly diluted the Zn concentration in various plant parts this also suggested by previous researchers (46).

**Table 5.** Effect of fertility, mulch and phosphorus levels on soil properties after harvest of sweet corn

| Treatment | pH | | EC ($dsm^{-1}$) | | OC (%) | | Available N (kg $ha^{-1}$) | | Available $P_2O_5$ (kg $ha^{-1}$) | | Available $K_2O$ (kg $ha^{-1}$) | | Available Zn (kg $ha^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2013 | 2014 | 2013 | 2014 | 2013 | 2014 | 2013 | 2014 | 2013 | 2014 | 2013 | 2014 | 2013 | 2014 |
| **Fertility levels** | | | | | | | | | | | | | | |
| $F_1$: 75 % RDF | 7.289 | 7.305 | 0.328 | 0.331 | 0.329 | 0.329 | 180.13$^{c}$ | 177.24$^{c}$ | 21.31$^{c}$ | 20.64$^{c}$ | 166.39$^{c}$ | 164.59$^{c}$ | 0.53$^{b}$ | 0.50$^{b}$ |
| $F_2$: 100 % RDF | 7.304 | 7.343 | 0.331 | 0.333 | 0.331 | 0.330 | 192.49$^{b}$ | 188.79$^{b}$ | 25.67$^{b}$ | 24.38$^{b}$ | 177.83$^{b}$ | 176.65$^{b}$ | 0.58$^{a}$ | 0.55$^{a}$ |
| $F_3$: 125 % RDF | 7.328 | 7.344 | 0.333 | 0.334 | 0.332 | 0.334 | 206.34$^{a}$ | 202.15$^{a}$ | 27.97$^{a}$ | 26.20$^{a}$ | 190.29$^{a}$ | 187.69$^{a}$ | 0.60$^{a}$ | 0.56$^{a}$ |
| **Mulch (kg $ha^{-1}$)** | | | | | | | | | | | | | | |
| $M_1$: Soil Mulch | 7.297 | 7.313 | 0.329 | 0.332 | 0.328 | 0.328 | 184.07$^{b}$ | 179.73$^{b}$ | 24.04$^{b}$ | 22.87$^{b}$ | 174.28$^{b}$ | 172.04$^{b}$ | 0.56$^{b}$ | 0.53$^{b}$ |
| $M_2$: Straw Mulch | 7.317 | 7.349 | 0.332 | 0.334 | 0.333 | 0.333 | 201.91$^{a}$ | 199.06$^{a}$ | 25.93$^{a}$ | 24.61$^{a}$ | 182.07$^{a}$ | 180.58$^{a}$ | 0.58$^{a}$ | 0.54$^{a}$ |
| **Phosphorus levels** | | | | | | | | | | | | | | |
| $P_1$: 100 % RDP | 7.287 | 7.307 | 0.328 | 0.331 | 0.329 | 0.327 | 182.63$^{c}$ | 178.30$^{c}$ | 21.89$^{c}$ | 20.58$^{c}$ | 171.47$^{c}$ | 170.35$^{c}$ | 0.58$^{a}$ | 0.55$^{a}$ |
| $P_2$: 150 % RDP | 7.308 | 7.330 | 0.330 | 0.332 | 0.330 | 0.331 | 192.23$^{b}$ | 189.00$^{b}$ | 25.09$^{b}$ | 24.00$^{b}$ | 178.46$^{b}$ | 176.78$^{b}$ | 0.57$^{ab}$ | 0.54$^{a}$ |
| $P_3$: 200 % RDP | 7.327 | 7.355 | 0.333 | 0.335 | 0.333 | 0.334 | 204.11$^{a}$ | 200.88$^{a}$ | 27.96$^{a}$ | 26.65$^{a}$ | 184.59$^{a}$ | 181.80$^{a}$ | 0.55$^{b}$ | 0.52$^{b}$ |
| **F values** | | | | | | | | | | | | | | |
| RDF | 0.67$^{ns}$ | 1.42$^{ns}$ | 1.51$^{ns}$ | 2.40$^{ns}$ | 0.33$^{ns}$ | 1.14$^{ns}$ | 15.96$^{***}$ | 15.62$^{***}$ | 23.65$^{***}$ | 41.96$^{***}$ | 67.00$^{***}$ | 91.98$^{***}$ | 25.19$^{***}$ | 13.72$^{***}$ |
| Mulch | 0.52$^{ns}$ | 2.70$^{ns}$ | 1.90$^{ns}$ | 0.58$^{ns}$ | 2.46$^{ns}$ | 3.11$^{ns}$ | 28.76$^{***}$ | 21.70$^{***}$ | 6.69$^{*}$ | 9.82$^{*}$ | 21.37$^{***}$ | 37.66$^{***}$ | 5.02$^{*}$ | 20.14$^{*}$ |
| RDP | 1.29$^{ns}$ | 2.73$^{ns}$ | 2.74$^{ns}$ | 3.12$^{ns}$ | 0.50$^{ns}$ | 3.03$^{ns}$ | 33.70$^{***}$ | 25.87$^{***}$ | 41.09$^{***}$ | 40.94$^{***}$ | 13.38$^{***}$ | 11.7$^{***}$ | 8.33$^{**}$ | 16.22$^{**}$ |
| RDF × Mulch | 0.88$^{ns}$ | 0.25$^{ns}$ | 0.77$^{ns}$ | 0.22$^{ns}$ | 0.11$^{ns}$ | 0.06$^{ns}$ | 0.04$^{ns}$ | 0.04$^{ns}$ | 0.43$^{ns}$ | 0.32$^{ns}$ | 0.29$^{ns}$ | 0.39$^{ns}$ | 0.01$^{ns}$ | 0.45$^{ns}$ |
| Mulch × RDP | 0.83$^{ns}$ | 0.82$^{ns}$ | 0.50$^{ns}$ | 0.66$^{ns}$ | 0.48$^{ns}$ | 0.58$^{ns}$ | 0.17$^{ns}$ | 0.21$^{ns}$ | 0.18$^{ns}$ | 0.17$^{ns}$ | 0.01$^{ns}$ | 0.01$^{ns}$ | 0.11$^{ns}$ | 0.01$^{ns}$ |
| RDF × RDP | 0.98$^{ns}$ | 0.78$^{ns}$ | 0.80$^{ns}$ | 0.87$^{ns}$ | 0.22$^{ns}$ | 0.28$^{ns}$ | 0.10$^{ns}$ | 0.24$^{ns}$ | 0.07$^{ns}$ | 0.08$^{ns}$ | 0.30$^{ns}$ | 0.32$^{ns}$ | 0.01$^{ns}$ | 0.01$^{ns}$ |
| RDF × Mulch × RDP | 0.54$^{ns}$ | 0.34$^{ns}$ | 0.81$^{ns}$ | 0.16$^{ns}$ | 0.06$^{ns}$ | 0.41$^{ns}$ | 0.91$^{ns}$ | 0.87$^{ns}$ | 0.53$^{ns}$ | 0.56$^{ns}$ | 0.00$^{ns}$ | 0.01$^{ns}$ | 0.01$^{ns}$ | 0.01$^{ns}$ |
| Initial values | 7.38 | 7.40 | 0.34 | 0.32 | 0.33 | 0.32 | 190.13 | 187.58 | 19.11 | 18.77 | 182.17 | 180.31 | 0.47 | 0.49 |

RDF: recommended dose of fertiliser; RDP: recommended dose of phosphorus; EC: electrical conductivity; OC: organic carbon; N: nitrogen; $P_2O_5$: phosphorus pentoxide; $K_2O$: potassium oxide; Zn: zinc; ns: non-significant. *Significant at $p \leq 0.05$; **significant at $p \leq 0.01$; ***significant at $p \leq 0.001$. Means with different letters within a column are significantly different at $p \leq 0.05$ according to Tukey's test.

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The treatments showed no significant effects on the chemical properties of soil, including pH, EC and OC. The available N, K and P in soil after harvesting of the crop increased significantly with corresponding increase in the fertility level and found maximum at highest 125 % RDF fertility level. However, the available Zn significantly enhanced to 100 % RDF only (Table 5). The extent of increase in the uptake of N, K and Zn was comparatively lower with increase in rate of fertility levels. Negative nutrient balance (available N and Zn) in soil after harvest of crop were noted in order of increase in fertility as 125 % RDF > 100 % RDF > 75 % RDF which was reveres in term of K. The nutrient flux depends on balance between soil available nutrients, replenishment of its ions and degree of nutrient depletion from the soil. This is related to rate and quantity of applied nutrients released to soil solution. The variation in residual nutrient content of the soil is well expected due to varied absorption of nutrients by the plants. Plant mobilises large quantities of nutrients from soil solution apart from applied nutrients. Some of nutrients besides uptake significantly enhanced the residual nutrients in soil. The results are conformity with the finding of (47–50).

The available N, P, K and Zn in the soil after harvest of the crop increased significantly and found maximum with straw mulch (Table 5). The extent of increase in the uptake of nutrients was comparatively lower than the increase in their rate of application. More available N, K and Zn in soil found after harvest of crop in straw mulch field. Above results might be due to mineralisation of straw by various microbes at moderate temperature and optimum moisture content.

The available N, P and K content of soil after harvesting of the crop increased significantly with corresponding increase in the P level and found maximum at highest 200 % RDP fertility level (Table 5). The nutrients in soil as estimated after the crop harvest were found in the order of 200 % RDP > 150 % RDP > 100 % RDP. Though the trend for Zn was reversed and it decreased with increase in the levels of P. This variation in residual nutrient content of soil explains the balance between applied nutrients and their uptake. Differential absorption of nutrients by the plants is natural. The nutrient profiles depend on balance between influx and replenishment of ions and degree of the soil nutrient depletion, which is related to rate and amount of nutrients released from soil solid phase to soil solution. Higher applied P undergoes various process of fixation and losses thus caused negative apparent loss at $P_3$ (Fig. 3). Plants can mobilise large quantities of nutrients from soil solution apart from applied nutrient. Result confirms the finding of earlier researchers (16). Increased P nutrition probably enhanced root growth; plant residues and microbial activity that uplift the soil nutrient status after decomposition during cropping. Howbeit P-Zn antagonism in rhizosphere reduced the available Zn availability as found least at 130 kg $P_2O_5$ $ha^{-1}$.

## 4. Conclusion

The results obtained from the study revealed that application of 125 % recommended dose of fertilisers (RDF) to sweet corn improved nutrient content (nitrogen (N); phosphorus (P); potassium (K); zinc (Zn)), uptake and enhanced soil nutrient status after two years. However, it was statistically at par with 100 % RDF and proved significantly superior only to 75 % RDF. Application of higher RDF at 125 % resulted in more N and Zn loss from the soil. Application of rice straw mulch at 6 t $ha^{-1}$ proved better than soil mulch and recorded markedly higher nutrient content (N, P, K and Zn) and their uptake; soil nutrient status in rainfed sweet corn. Application of 200 % recommended dose of phosphorus (RDP) (130 Kg $ha^{-1}$) recorded highest values of N, P and K in various plant parts. Zinc content was higher in least RDP. Higher P rate depleted more nutrients from soil and recorded apparent loss of soil P. Thus, the study underscores the importance of combined use of optimum fertility levels and rice straw mulching practices for improving nutrient uptake and sustaining soil fertility in rainfed sweet corn.

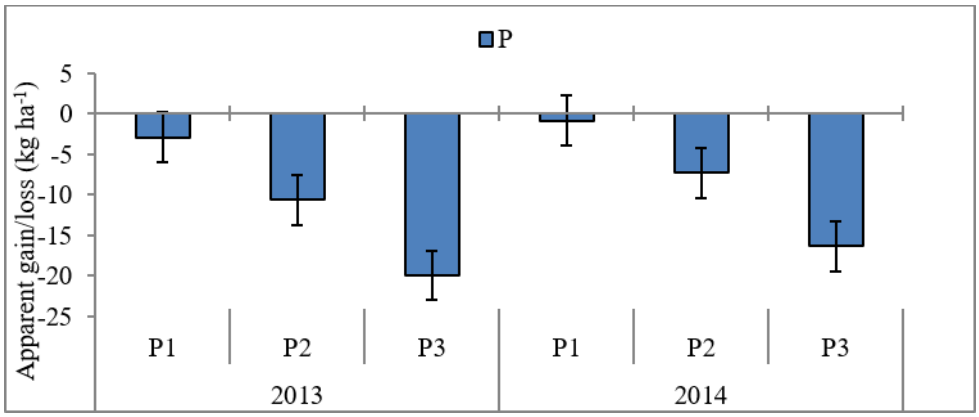



**Fig. 3.** Effect of phosphorus levels on apparent gain/loss of soil available phosphorus.
Error bars represent ± standard error of means.

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## Authors' contributions

SKC contributed to methodology, statistical analysis, investigation and writing the original draft. SPS contributed to conceptualisation, funding acquisition, writing, reviewing and editing and supervision. MKS contributed to investigation, formal analysis and writing the original draft. USS, MPN and SK contributed to statistical analysis and writing the original draft. VP contributed to final editing of the manuscript. All authors have read and approved the final manuscript.

## Compliance with ethical standards

### Conflict of interest

Authors do not have any conflict of interests to declare.

### Ethical issues

None

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