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Impact assessment of seedling age on soil properties, nutrient uptake and quality of sweet corn (*Zea mays saccharata* L.) under different sources of nutrients

Bisma Jan, M. Anwar Bhat, Tauseef A. Bhat, Aijaz Nazir, Khursheed Ahmad Dar, Tajamul Mansoor, Nasir Bashir Naikoo; Zahoor Ahmad Dar, Audil Gull

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Authors:
B. Jan, T. A. Bhat ✉, K. A. Dar, T. Mansoor, N. B. Naikoo, A. Gull
Faculty of Agriculture, Wadura Sopore, SKUAST Kashmir, India

M. A. Bhat,
Directorate of Extension, SKUAST Kashmir, India

A. Nazir,
Agromet Unit, Faculty of Horticulture SKUAST-Kashmir, India

Z. A. Dar ✉,
4Dryland Agriculture Research station, Budgam, SKUAST-Kashmir, India

✉ tauseekk@gmail.com,
zahoorpbg@gmail.com

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Abstract

To determine the effect of the age of seedlings under different sources of nutrients on soil properties, nutrient uptake, and quality of the sweet corn, an experiment was laid out in randomized complete block design (RCBD) with factorial arrangement during the *Kharif* season of 2020. The experiment consisted of two factors: seedling ages (12, 22, and 32 days old) and nutrient sources (control, RDF, ½ RDF + FYM, ½ RDF + VC, and ½ RDF + PM). Organic sources of nutrients viz. FYM, vermicompost, and poultry manure were given on N equivalent basis. Results showed that transplanting 22 days old seedlings performed better and recorded higher NPK uptake in grain as well as stover with a significant difference, which was directly associated with its high dry matter accumulation. However, no significant difference was observed in the nutrient content of N, P, and K. Significantly higher grain and stover yield was realized by transplanting 22 days old seedlings. Application of ½ RDF + PM led to a significant increase in nutrient content and uptake in both grain and stover as compared to the sole application of RDF. The higher nutrient uptake was ultimately responsible for a higher yield of sweet corn. Application of ½ RDF + FYM was statistically at par with ½ RDF + VC to nutrient uptake and yield. The quality of kernels in terms of TSS, protein, Fe, and Zn content was notably influenced by sources of nutrients with the highest results under the application of ½ RDF + PM. Higher values for Fe and Zn content of grain were reported in the case of 22 days old seedlings with no significant difference to the rest of the seedling ages. Furthermore, the age of seedlings didn't have a significant effect on post-harvest soil Physico-chemical properties however a significant improvement was noted in plots fertilized with ½ RDF + PM.

Keywords nutrient uptake, seedling age, sweet corn, transplanting

Introduction

Sweet corn is a profitable crop that can act as an alternative to the farming community for ensuring food and nutrition as well as financial security. It has the potential to generate more employment opportunities with the diversification of production in the rural areas. Therefore, to exploit the maximum potential yield of sweet corn, transplanting of sweet corn is a promising strategy for crop establishment that assures high and uniform crop stands [1-2]. However, the seedlings should be transplanted at an appropriate seedling age [3]. Koudjega et al., [4] reported that transplanting aged seedlings results in lesser uptake of nutrients, thereby reducing the yield of the crop. Another important factor determining the growth and productivity of sweet corn is fertilization. Continuous application of the huge amount of nutrients through chemical fertilizer leads to potential environmental risks [5] while reducing the recovery of nutrients as the nutrients are not completely uptaken by the crop, and are lost to the environment through leaching, volatilization, and denitrification. Sole application of inorganic nutrients affects the soil organic matter and soils with low soil organic matter content are considered to be poor soils in terms of CEC, pH buffer capacity that leads to continuous nutrient losses [6]. Thereby growing interest in the use of organic sources as an alternative cannot be overlooked [7]. It is evident from previous research that the addition of organic manures benefits the crop in terms of its growth and yield. Moreover, organic sources contribute to the addition of nutrients other than NPK, ensuring their availability in such forms that can be easily uptaken by plants over a longer period and also stimulates microbial activity [8]. But organic fertilizers cannot completely replace inorganic fertilizers to meet the ever-rising demands, therefore, integrated use of inorganic and organic sources of nutrients provides a reliable alternative. Chemical fertilizers are capable of releasing nutrients more quickly, thus making them readily available to plants at earlier stages of growth while organic sources release plant nutrients slowly into the rhizosphere through mineralization, which ensures their adequate availability through the entire crop growth period leading to profound influence on the growth characters. Therefore, integrated use of both sources can interact positively and increase the efficiency of chemical fertilizers by synchronizing the demand for nutrients with the supply of nutrients throughout the growth period.

Methodology

Location and weather conditions of the experiment site
A field investigation to determine the influence of the age of seedlings on soil properties, nutrient content, and uptake and quality of sweet corn under various sources of nutrients was undertaken. The location of the experiment was the Research farm of Agronomy at FoA, SKUAST-K, Sopore, Jammu and Kashmir, geographically located at an altitude of 1587 m AMSL, 34° 34´ N latitude and 74°40´ E longitude. The weather data for *Kharif*-2020 (Figure 1) was recorded from the Meteorological Observatory located at Shalimar. It was observed that weekly minimum and maximum temperatures ranged between 7.5 to 18.1 °C and 23.8 to 35 °C respectively. A rainfall of 166 mm was noted during the period.

Soil physico-chemical properties
The experimental site was well-drained with uniform topography. Before the commencement of the experiment, soil samples were collected randomly from the experimental field. The samples collected from a depth of 0-15 cm were mixed to form a composite sample which was used for the estimation of the soil physical and chemical properties (Table 1). The analysis of soil samples revealed that the soil was neutral in reaction and silty clay loam in texture. Furthermore, the soil was found to be medium concerning available nitrogen and phosphorus.

Experimental setup
The trial was in a Randomized Complete Block Design with a Factorial arrangement. It was a two-factor experiment replicated thrice. Factor A consisted of seedlings ages: 12, 22, and 32 days old. Factor B consisted of nutrient sources: control, RDF, ½ RDF + FYM, ½ RDF + VC, and ½ RDF + PM. Organic sources of nutrients *viz*. FYM, vermicompost, and poultry manure on N equivalent basis were applied 15 days before transplantation as per the treatment requirement. While in the case of

inorganic sources recommended dose of P, K and Zn was given at the time of transplanting

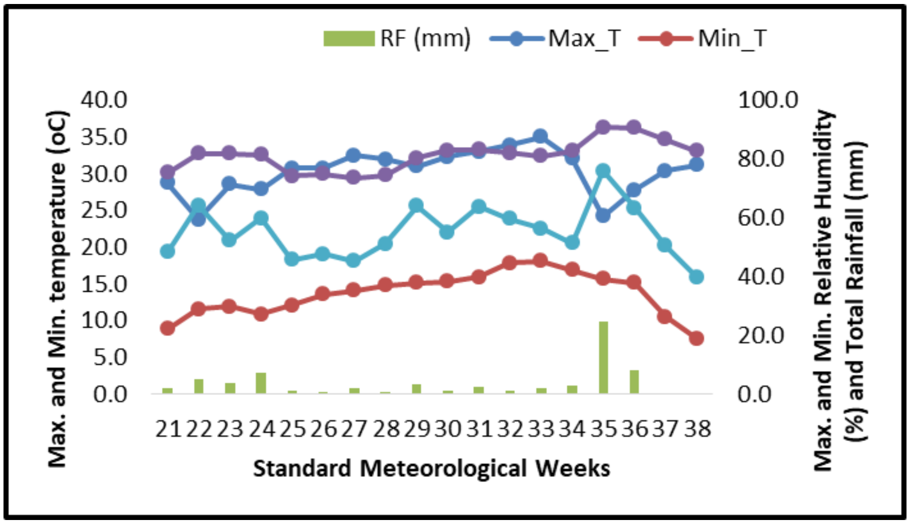

Figure 1. Mean weekly meteorological parameters during Kharif-2020

Table 1. Initial soil physico-chemical properties

SN.	Parameter	Value	Remark
1	pH	6.67	Neutral
2	Electric conductivity	0.36 dSm^{-1}	Normal
3	Organic carbon	0.71 %	Medium
4	Bulk density	1.32 g cm^{-3}	-
5	Texture	silty clay loam	-
6	Available N	304.67 kg ha^{-1}	Sufficient
7	Available P	17.20 kg ha^{-1}	Sufficient
8	Available K	181.50 kg ha^{-1}	Sufficient

along with a half dose of recommended N, whereas the remaining half dose of N was applied in two equal splits at the knee-high stage and tasseling. All seedlings of different ages were transplanted to the main field on the same date. The land was configured for the transplantation of seedlings by opening furrows (row) at a distance of 75 cm with 20 cm intra-row spacing. The seedlings were carefully transplanted with minimum disturbance to the root system for proper establishment and were watered immediately after transplanting to facilitate the establishment of seedlings. Cobs were picked up after the milking stage. The period of picking ranged from 90 to 105 DAT. Green fodder was immediately harvested after cob picking.

Data compilation

For plant analysis, the samples were collected at the time of harvest and processed following the standard procedure. The NPK content was recorded in grain and stover separately. For the determination of N micro Kjeldahl digestion method was used, venedo molybdophosphoric yellow color method was used for P estimation and K content was recorded using a flame photometer. For the calculation of nutrient uptake by the grain and stover, the estimated values of nutrient content in grain and stover respectively were used with the help of the given formula:

$$NU\ (kg\ ha^{-1}) = \frac{NC\ (\%) \times DM}{100} \qquad (1)$$

where, NU= Nutrient uptake; NC= Nutrient content and DM= Weight of dry matter

Among the evaluated quality parameters, total soluble solids were determined using a hand refractometer and mentioned in Brix. The estimated value of grain nitrogen content was used to calculate its protein content by multiplying nitrogen content with a factor of 5.98. The Fe and Zn content in the digested samples of sweet corn grains was determined by Atomic Absorption Spectrometry (AAS). The soil was analyzed again just after the harvest and separate soil samples were collected from each treatment. Following the standard procedure, the samples were processed and analyzed. Soil bulk density was determined by using the tapping method. Soil pH and electrical conductivity (EC) were measured using a pH meter and conductivity meter, respectively. Organic carbon was determined by Walkley and Black chromic acid wet oxidation method by oxidizing organic carbon in the soil sample with potassium dichromate in presence of sulphuric acid as the source of energy for the reaction to take place. Soil-available NPK content was determined using the alkaline potassium permanganate oxidation method, Olsen's extractant using a spectrophotometer at 660 nm wavelength, and neutral normal ammonium acetate solution extraction using a flame photometer respectively. The estimated values of N uptake under various treatments were further used to study various N use efficiencies using the given formulas:

$$AE = \frac{\text{GY of N fertilized} - \text{GY of control}}{\text{N applied}} \qquad (2)$$

$$PE = \frac{\text{GY of N fertilized} - \text{GY of control}}{\text{NU of N fertilized} - \text{NU of control}} \qquad (3)$$

$$PFP = \frac{\text{GY}}{\text{N applied}} \qquad (4)$$

$$RE = \frac{\text{NU of N fertilized} - \text{NU of control}}{\text{N applied}} \qquad (5)$$

where, AE= Agronomic efficiency, GY= grain yield; PE= Physiological efficiency;
NU= Nitrogen uptake; PFP= Partial Factor Productivity and RE= Recovery efficiency.

Statistical analysis

The standard method of analysis of variance subjected to RCBD (Factorial) was employed for experimental data using R software [9]. LSD test at a 5 % probability level was used to test the difference among all the treatment means. Correlation of NPK uptake with grain yield and stover yield respectively was performed. Similarly, for analyzing and determining the association of sweet corn yield with nutrient uptake regression analysis of nutrient uptake with grain yield and stover yield respectively was performed using R software [9].

Results

Soil physico-chemical properties after harvest

A perusal of the data about soil physicochemical properties (Table 2) showed that the age of seedlings didn't influence the soil properties viz., organic carbon, pH, EC, bulk density, and available NPK significantly after crop harvest. Further, it was inferred from the data that sources of nutrients imposed a significant influence on soil available NPK after crop harvest. However other soil properties like pH, EC, organic carbon, and bulk density were not influenced significantly. Plots fertilized with ½ RDF + PM showed the highest soil available NPK which was significant to other sources of

Table 2. Soil physico-chemical properties influenced by age of seedlings and nutrient sources after harvest

Treatments	Organic carbon (%)	EC (dSm^{-1})	pH	Bulk density ($g\ cm^{-3}$)	Available N ($kg\ ha^{-1}$)	Available P ($kg\ ha^{-1}$)	Available K ($kg\ ha^{-1}$)
Age of seedling (days)							
A1: 12	0.71	0.33	6.66	1.31	301.218	17.135	155.67
A2: 22	0.71	0.33	6.64	1.30	298.9	15.753	151.69
A3: 32	0.72	0.32	6.64	1.30	304.422	17.411	156.20
SE(m)±	0.00	0.01	0.04	0.01	2.065	0.699	1.6094
CD (p ≤ 0.05)	NS	NS	NS	NS	NS	NS	NS
Sources of nutrients							
Control	0.70	0.33	6.71	1.30	279.28	11.28	138.41
RDF	0.70	0.33	6.72	1.31	295.59	14.80	150.50
½ RDF + FYM	0.71	0.34	6.62	1.30	305.44	17.74	157.36
½ RDF + VC	0.72	0.32	6.59	1.30	307.70	18.43	157.95
½ RDF + PM	0.72	0.33	6.59	1.30	319.56	21.58	168.38
SE(m)±	0.01	0.01	0.05	0.01	2.67	0.90	2.08
CD (p ≤ 0.05)	NS	NS	NS	NS	7.72	2.62	6.02

nutrients. Plots fertilized with ½ RDF + FYM were statistically at par with plots fertilized with ½ RDF + VC concerning soil available NPK.

Grain and stover yield

Regarding grain and stover yield, the data indicated that the age of seedlings lead to significant differences among the treatments as given in Table 3. Statistically higher grain and stover yield were recorded by transplanting 22 days old seedlings in comparison with other seedling ages. A yield advantage of 11.5 % and 12.3 % in grain and stover yield respectively was observed by transplanting 22 days old seedlings than transplanting 12 days old seedlings.

Table 3. Grain and stover yield of sweet corn influenced by age of seedlings and nutrient sources

Treatments	Grain yield ($q\ ha^{-1}$)	Stover yield ($q\ ha^{-1}$)
Age of seedling (days)		
A1: 12	14.58	74.76
A2: 22	16.26	83.97
A3: 32	12.74	66.40
SE(m)±	0.22	3.03
CD (p ≤ 0.05)	0.62	8.79
Sources of nutrients		
Control	10.17	56.99
RDF	16.06	82.59
½ RDF + FYM	14.14	69.89
½ RDF + VC	14.42	71.13
½ RDF + PM	17.84	94.61
SE(m)±	0.28	3.92
CD (p ≤ 0.05)	0.81	11.35

Transplanting 32 days old seedlings yielded significantly lower than 12 days old seedlings by around 14.4 % in grain yield and 12.6 % in stover yield. The effect of different sources of nutrients also showed significant differences concerning grain and stover yield. Application of ½ RDF + PM registered higher grain and stover yield with significant differences to other nutrient sources. In comparison with the application of RDF registered with 11.10 % more grain yield and 14.6 %, more stover yield was obtained by the use of ½ RDF + PM. Application of 50 percent RDF + PM produced 75.5 % more grain yield and RDF produced 58 % more grain yield than the control. Stover yield produced under the application of ½ RDF + PM was 66 % more than control and 44.9 % more under RDF than control. Furthermore, the yield obtained by the application of ½ RDF + FYM was statistically at par with the application of ½ RDF + VC.

Nutrient content and uptake studies

(a) Nitrogen

The grain and stover nitrogen content of sweet corn didn't vary significantly with the age of seedlings (Table 4). Data revealed that transplanting 22 days old seedlings recorded numerically higher nitrogen content of 1.34 % in grain and 0.65 % in stover followed by 12 days old seedlings. The lowest content in grain and stover was obtained from 32 days old seedlings. However, the data varied significantly concerning nutrient uptake by grain and stover of sweet corn. Nitrogen uptake of 21.95 kg ha^{-1} and 54.51 kg ha^{-1} from grain and stover respectively (Table 5) was recorded under transplanting 22 days old seedlings that showed a significant difference with 12 days old seedlings (Table 5). Among sources of nutrients, with the application of ½ RDF + PM statistically higher nitrogen content and uptake by grain were obtained with a value of 1.40 % and 25.07 kg ha-1 respectively, followed by RDF whereas under control nitrogen content and uptake by grain was lowest. In like manner, higher nitrogen content and uptake by stover, were observed under the use of ½ RDF + PM with a value of 0.71 % and 65.21 kg ha^{-1} respectively, followed by RDF whereas under control nitrogen content and uptake by stover were the lowest. However, the application of ½ RDF + VC was found statistically at par with the application ½ RDF + FYM.

Table 4. Nutrient content of grain and stover of sweet corn influenced by age of seedlings and nutrient sources

Treatments	Nitrogen content (%)		Phosphorus content (%)		Potassium content (%)	
	Grain	Stover	Grain	Stover	Grain	Stover
Age of seedling (days)						
A_1: 12	1.33	0.64	0.55	0.35	0.80	1.55
A_2: 22	1.34	0.65	0.57	0.36	0.81	1.57
A_3: 32	1.32	0.63	0.54	0.34	0.79	1.53
SE(m)±	0.006	0.006	0.01	0.01	0.01	0.01
CD ($p \leq 0.05$)	NS	NS	NS	NS	NS	NS
Sources of nutrients						
Control	1.25	0.56	0.49	0.30	0.76	1.50
RDF	1.36	0.67	0.58	0.37	0.81	1.57
½ RDF + FYM	1.31	0.62	0.53	0.32	0.78	1.53
½ RDF + VC	1.32	0.63	0.53	0.33	0.79	1.53
½ RDF + PM	1.40	0.71	0.62	0.42	0.85	1.61
SE(m)±	0.01	0.008	0.01	0.01	0.01	0.01
CD ($p \leq 0.05$)	0.03	0.02	0.03	0.03	0.04	0.04

(b) Phosphorus

Phosphorus content in grain and stover of the sweet corn didn't show significant variation in the age of seedlings. By transplanting 22 days old seedlings numerically higher phosphorus content of 0.57 % in grain and 0.36 % in stover was observed (Table 4). However, a significant variation was noted in phosphorus uptake with higher values observed under transplanting 22 days old seedlings in grain as well as stover (Table 5). The lowest uptake was obtained by transplanting 32-day-old seedlings.
Among sources of nutrients significantly higher phosphorus content of 0.62 % and uptake of

11.08 kg ha^{-1} by grain was observed with the application of ½ RDF + PM, followed by RDF. Similarly, the statistically higher phosphorus content of 0.42 % and uptake of 38.70 kg ha^{-1} by stover, was observed with the use of ½ RDF + PM and it was, followed by RDF. The lowest values of phosphorus content and uptake by grain as well as stover were observed with control.

Table 5. Nutrient uptake by grain and stover of sweet corn influenced by age of seedlings and nutrient sources

Treatments	Nitrogen uptake (kg ha^{-1})		Phosphorus uptake (kg ha^{-1})		Potassium uptake (kg ha^{-1})	
	Grain	Stover	Grain	Stover	Grain	Stover
Age of seedling (days)						
A1: 12	19.49	47.72	8.09	25.93	11.74	114.07
A2: 22	21.95	54.51	9.21	29.36	13.08	129.72
A3: 32	16.97	43.56	6.93	22.92	10.09	104.68
SE(m)±	0.35	1.65	0.20	0.31	0.26	0.96
CD (p ≤ 0.05)	1.02	4.95	0.58	0.94	0.75	2.90
Sources of nutrients						
Control	12.73	37.39	5.05	19.69	7.69	99.92
RDF	21.88	53.08	9.25	28.84	13.04	123.19
½ RDF + FYM	18.60	43.40	7.40	20.99	11.02	104.16
½ RDF + VC	19.07	43.90	7.62	22.13	11.31	105.72
½ RDF + PM	25.07	65.21	11.08	38.70	15.12	147.80
SE(m)±	0.46	1.89	0.20	0.39	0.33	1.38
CD (p ≤ 0.05)	1.32	5.67	0.58	1.15	0.97	4.14

(c) Potassium

The potassium content of 0.81 % in grain and 1.57 % in stover was recorded by transplanting 22 days old seedlings which were numerically higher than transplanting 12 days and 32 days old seedlings with no statistical difference (Table 4). However, significant variation was observed regarding potassium uptake among ages of seedlings with superior results for both grain and stover uptake registered by transplanting 22 days old seedlings (Table 5). Among sources of nutrients statistically higher potassium content of 0.85 % and uptake of 15.12 kg ha^{-1} by grain was recorded with the use of ½ RDF + PM followed by RDF. In like manner, the highest potassium content of 1.61 % and uptake of 147.80 kg ha^{-1} by stover, was noted under the use of ½ RDF + PM. The lowest values for content and uptake of potassium were observed under control in grain as well as stover of the sweet corn.

Correlation and regression analysis

The data revealed that grain yield possessed a significant association with NPK uptake. The grain yield showed a positive correlation of 0.81 with N uptake, 0.58 with P uptake, and 0.63 with K uptake at 0.1 % level of significance (Table 6).

Table 6. Correlation coefficients of nutrient uptake with grain yield and stover yield

Parameters	N uptake	P uptake	K uptake
Grain yield	0.81***	0.58***	0.63***
Stover yield	0.88***	0.64***	0.70***

*** Correlation coefficients at 0.1% level of significance

Likewise, a significant association of stover yield was observed with NPK uptake. Stover yield possessed a positive correlation of 0.88 with N uptake, 0.64 with P uptake, and 0.70 with K uptake. To determine the dependence of the yield of sweet corn on plant NPK uptake, regression analysis was performed. The data showed that R^2 between grain yield and N uptake was 65 % which implies that N uptake determines the 65 % grain yield of sweet corn (Figure 2 and Table 7). In like manner, P uptake was 33.9 % and K uptake was 39.8 % in relationship with the grain yield of sweet corn. In the case of stover yield N uptake predicted 76.6 % of stover yield, P uptake predicted 40.7 % of stover yield and K uptake predicted 49.3 % of stover yield.

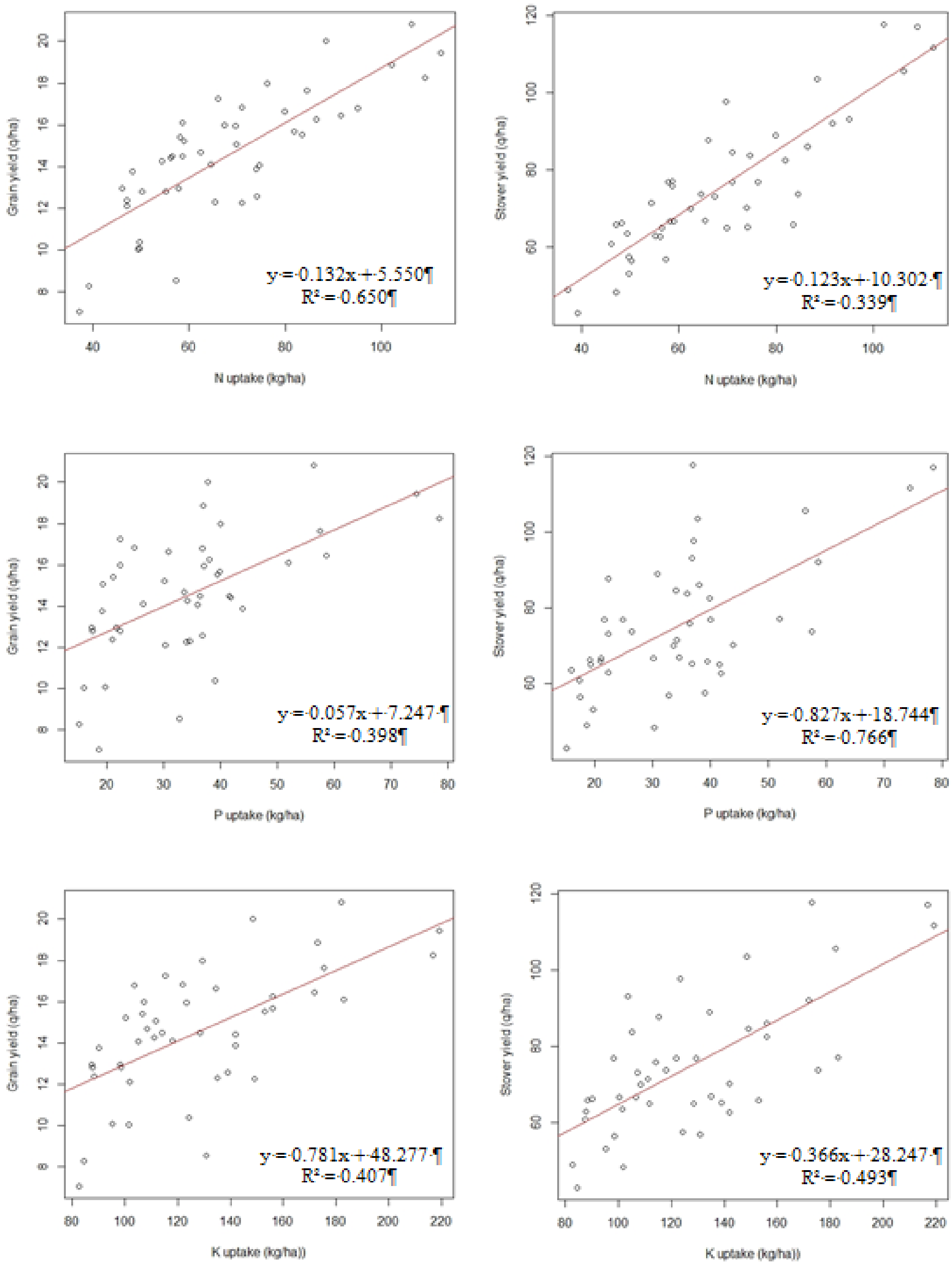

Figure 2. Response of grain and stover yield of sweet corn to NPK uptake

Table 7. Linear regression model of nutrient uptake with grain yield and stover yield

Parameters	Regression model	Multiple R-squared	Level of significance
Grain yield	$y_1 = 0.132x1 + 5.550$	$R^2 = 0.650$	0.001
Grain yield	$y_1 = 0.123x2 + 10.302$	$R^2 = 0.339$	0.001
Grain yield	$y_1 = 0.057x3 + 7.247$	$R^2 = 0.398$	0.001
Stover yield	$y_2 = 0.827x1 + 18.744$	$R^2 = 0.766$	0.001
Grain yield	$y_2 = 0.781x2 + 48.277$	$R^2 = 0.407$	0.001
Grain yield	$y_2 = 0.366x3 + 28.247$	$R^2 = 0.493$	0.001

y_1 is grain yield, y_2 is stover yield, x_1 is N uptake, x_2 is P uptake, x_3 is K uptake

N use efficiencies

N use efficiencies showed significant variation due to the age of seedlings (Table 8). The efficiency of N expressed in terms of AE which denotes yield gain contributed by applied N in comparison to soil N and was obtained significantly higher under transplanting 32 days old seedlings and the least AE was observed with transplanting 22 days old seedlings. Another parameter of evaluating N use efficiency is PFP which indicates the yield produced per unit of N applied. It was noticed that significantly higher PFP with transplanting 22 days old seedlings *i.e.*, 13.55 kg kg^{-1} whereas the lowest PFP of 12.15 kg kg^{-1} was recorded with transplanting 32 days old seedlings.

Table 8. Nitrogen AE, PFP, PE, and RE of sweet corn influenced by age of seedlings and nutrient sources

Treatments	Agronomic efficiency (kg kg^{-1})	Partial factor productivity (kg kg^{-1})	Physiological efficiency (kg kg^{-1})	Recovery efficiency (%)
Age of seedling (days)				
A_1: 12	3.67	12.15	25.53	14.44
A_2: 22	3.23	13.55	17.32	16.92
A_3: 32	3.99	10.62	32.56	13.30
SE(m)±	0.16	0.18	3.67	1.18
CD ($p \leq 0.05$)	0.48	0.52	10.63	N.S.
Sources of nutrients				
Control	0.00	8.47	0	0
RDF	4.91	13.39	29.26	20.70
½ RDF + FYM	3.31	11.79	40.32	9.53
½ RDF + VC	3.54	12.02	36.18	10.71
½ RDF + PM	6.39	14.87	19.92	33.47
SE(m)±	0.21	0.23	4.74	1.52
CD ($p \leq 0.05$)	**0.62**	**0.67**	**13.72**	**4.41**

PE is a plant-based indicator of N efficiency that denotes the ability of the plant to produce yield per unit of N uptaken by the plant. Transplanting 22 days old seedlings resulted in PE of 17.32 kg kg^{-1}. Significantly highest PE of 32.56 kg kg^{-1} was observed with transplanting 32 days old seedlings which was followed by 12 days old seedlings. One more parameter for analyzing N use efficiency is RE which shows the comparative uptake of N applied to soil N. The highest RE 16.92 % was recorded with transplanting 22 days old seedlings and the lowest RE of 13.30 % was observed under 32 days old seedlings. Different nutrient sources exerted a marked influence with significant variations on N use efficiency. The highest AE of 6.39 kg kg^{-1} was noted with the use of ½ RDF + PM followed by an AE of 4.91 kg kg^{-1} under the use of RDF. The highest PFP of 14.87 kg kg^{-1} was noted with the use of ½ RDF + PM and the lowest PFP of 8.47 kg kg^{-1} was registered under control. Application of ½ RDF + VC resulted in 12.02 kg kg^{-1} of PFP, with no significant difference shown by the use of ½ RDF + FYM. For PE, the highest value of 40.32 kg ka^{-1} was noticed with the application of ½ RDF + FYM being at no significant difference with the use of ½ RDF + VC. Application of RDF resulted in 29.26 kg kg^{-1} of PE, whereas 19.92 kg kg^{-1} was observed with ½ RDF + PM. One more parameter was RE, in which the highest results were given by ½ RDF + PM at a significant difference with the rest of the treatments. Use of RDF registered RE of 20.70 kg kg^{-1}.

Quality parameters

(a) TSS

It was observed from Table 9 that the TSS value for sweet corn kernels showed no statistical variation among the ages of seedlings. However, numerically higher results were given by transplanting 22-day-old seedlings. Transplanting 12 days old seedlings was found to be better than transplanting 32 days old seedlings. Moreover, sources of nutrients had a significant effect on TSS value with a statistically higher value of 16.03 °Brix recorded under the application of ½ RDF + PM, and in the case of control lowest value of 14.80 °Brix was recorded. The use of ½ RDF + VC and ½ RDF + FYM were statistically similar in terms of TSS value with a numerically higher value under the former.

Table 9. Grain quality of sweet corn is influenced by age of seedlings and nutrient sources

Treatments	Iron content in grain (ppm)	Zinc content in grain (ppm)	Iron uptake in grain (kg ha^{-1})	Zinc uptake in grain (kg ha^{-1})	Protein content in grain (%)	TSS (°Brix)
Age of seedling (days)						
A1: 12	94.94	34.95	1.401	0.519	7.94	15.55
A2: 22	95.19	35.70	1.567	0.584	8.02	15.67
A3: 32	93.39	34.91	1.207	0.455	7.90	15.33
SE(m)±	0.89	0.44	0.0253	0.0118	0.04	0.12
CD (p ≤ 0.05)	**NS**	**NS**	**0.0733**	**0.0342**	**NS**	**NS**
Sources of nutrients						
Control	86.57	29.39	0.884	0.299	7.48	14.80
RDF	99.16	37.33	1.593	0.599	8.14	15.79
½ RDF + FYM	89.80	33.19	1.272	0.466	7.86	15.31
½ RDF + VC	91.59	34.76	1.327	0.497	7.90	15.66
½ RDF + PM	105.42	41.24	1.881	0.737	8.39	16.03
SE(m)±	1.15	0.57	0.0327	0.0152	0.048	0.17
CD (p ≤ 0.05)	**3.33**	**1.64**	**0.0946**	**0.0441**	**0.14**	**0.52**

(b) Protein

Data from Table 9 showed that no significant variation was noticed regarding the protein content of grains among different ages of seedlings. However, a numerically higher value of 8.02 % was obtained by transplanting 22-day-old seedlings. Sources of nutrients exerted a significant effect on the protein content of grains with significantly higher results noted under the application of ½ RDF + PM. A value of 7.48 % was recorded in the case of control which was found to be the lowest among all treatments. Furthermore, the use of ½ RDF + VC and ½ RDF + FYM were statistically at par in terms of protein content with numerically higher values under the former.

(c) Zn and Fe content

The data given in Table 9 showed that by transplanting 22 days old seedlings higher Fe and Zn content of grains were recorded but no significant variation was observed in comparison with other seedling ages. However, a significant variation was observed among sources of nutrients with higher values for Fe (105.42 ppm) and Zn (41.24 ppm) content under the application of ½ RDF + PM and the lowest value of Fe (86.57 ppm) and Zn (29.39 ppm) content recorded in case of control. Plots fertilized with ½ RDF + VC and ½ RDF + FYM were statistically similar regarding Fe and Zn content of grains.

Discussion

The age of seedlings didn't impose any significant influence on the properties of soil like pH, EC, organic carbon, bulk density, and available NPK after the harvest of the crop. However, sources of nutrients imposed a significant influence on the soil available NPK after the crop harvest. Significant differences observed in plots fertilized with ½ RDF + PM for the availability of NPK in the soil can be assigned to the addition of nutrients to the soil from the mineralization of organic sources of nutrients capable of maintaining the nutrient content of the soil. While left-over nutrients in soil after meeting the crop requirements under the sole application of inorganic sources are not considerable enough due to greater losses of nutrients through leaching and volatilization. The given results are in line with the findings of [10-12].

Significantly higher grain and stover yield registered with transplanting 22 days old seedlings might be associated with enhanced vegetative growth and efficient utilization of available resources that resulted in a high assimilation rate and accumulated more dry matter which positively affected the yield. Thus, the production of high green cob and green fodder yield will ultimately result in higher grain and stover yield. The results are in coherence with [13-14]. In like manner, treatment ½ RDF + PM resulted in a significantly higher grain and stover yield. This was attributed to the proper availability and acquisition of nutrients that enhanced the overall performance of the crop. As the yield of a crop is determined by its genetic potential and growth factors. Differential availability of nutrients in different nutrient sources might have restricted the exploitation of the genetic potential of the crop to a large extent which resulted in a declining trend of grain and stover yield among various sources of nutrients. As observed in the case of control nutrient stress led to poor results in terms of growth as well as yield parameters. Moreover, the contribution of micronutrients from the organic sources that might have contributed to the elevation of yield cannot be ignored [15]. The findings are supported by [16-17].

It was further inferred that the nutrient content of grain and stover didn't vary significantly with the age of seedlings. However, higher nutrient uptake by grain and stover was realized by transplanting 22 days old seedlings at a significant difference with the rest of the ages of seedlings. Since nutrient uptake is determined from dry matter accumulation by multiplying the nutrient content with dry matter produced by the plant. Therefore, higher dry matter production under transplanting 22days old seedlings may be ascribed as the reason for the higher nutrient uptake. Similar results were reported by [4, 18]. Among sources of nutrients application of ½ RDF + PM showed significantly better performance than other sources of nutrients. The possible reason could be that organic sources of nutrients act as a reservoir of nutrients with slow nutrient release patterns which enables their availability in adequate amounts at every crop growth stage and thus resulted in a higher concentration of NPK in grain as well as stover of sweet corn. Adeniyan et al., [19] advocated that organic sources retain nutrients for a longer period while inorganic sources provide a ready source of nutrients to the crop, but are available for a shorter period as they are prone to various losses such as leaching which is in accordance to our findings. Furthermore, higher nutrient content coupled with greater biomass production resulted in a significant difference in nutrient uptake among different sources of nutrients. The findings are in agreement with Almaz et al., [20] who concluded that the integration of ½ NPK and ½ of PM resulted in the highest NPK uptake. Similar findings were reported by Waniyo et al., [21]. More importantly, higher levels of nutrients available in PM and favorable C: N ratio for rapid mineralization and subsequent addition of nitrogen and phosphorus to the soil resulted in enhanced content of nutrients and ultimately led to higher nutrient uptake by grain as well as stover. Furthermore, P is supposed to have a significant role in the development of roots, thus governing the ability of the plant to uptake nutrients. The comparatively higher availability of P in poultry manure can be attributed as another reason for more nutrient uptake under the application of ½ RDF + PM. The trend followed for grain and stover yield in both factors was found parallel to NPK uptake by the plant. As observed in regression analysis of grain and stover yield with NPK uptake, 33.9 % to 65 % in grain yield and 40.7 % to 76.6 % in stover yield are determined by NPK uptake. Nitrogen alone predicted 65 % of grain yield and 76.6% of stover yield, thus indicating the importance of N nutrients. The findings are in coherence with Canatoy et al., [16].

Among the seedling ages, it was observed that the highest AE and PE were recorded in 32 days old seedlings whereas PPF and RE were recorded highest with transplanting 22 days old seedlings. A similar pattern of RE was reported by Salem et al., [22]. Koudjega et al., [4] advocated that older seedlings recorded higher values of RE whereas younger seedlings recorded higher values of PE which was attributed to the reason that younger seedlings uptake more N. The nutrient use efficiency of plants is affected by various factors among which crop efficiency, fertilization strategies, and fertilizer source are of great importance from an agronomic point of view. Reducing nutrient losses through leaching, volatilization or denitrification helps to increase the nutrient use efficiency of a crop production system. The slow release of nutrients from organic sources which enables their secured availability throughout the crop period resulted in good uptake of nutrients particularly N. Thus, the use of both organic and inorganic nutrient sources in integration gave better results than the sole use of inorganic N by synchronizing the demand of the crop with the supply of nutrients which led to an increase in N use of efficiency. The results are supported by Wang et al., [23].

The results further indicated no significant variation in total soluble solids (TSS), protein, Fe, and Zn content of grains due to the age of seedlings but numerically higher TSS, protein, Fe, and Zn content were obtained by transplanting 22 days old seedlings which may be due to its enhanced performance than rest of the seedlings. The results are consistent with the findings of [13, 24]. Sources of nutrients influenced the quality parameters *viz*., TSS and protein content significantly. Higher TSS and protein observed under the application of ½ RDF + PM may be possible because of higher photosynthetic performance observed under the application of ½ RDF + PM that resulted in the accumulation of more sugars. Moreover, increased uptake of nitrogen directly affected the protein concentration in grains as nitrogen forms an essential constituent of proteins. The results are supported by [12, 24-25]. In like manner, a significant effect was observed on Fe and Zn content of sweet corn kernels with the highest content recorded under the application of ½ RDF + PM which may be attributed to the availability of a considerable amount of micronutrients in poultry manure. The results are supported by Fakeerappa and Hulihalli [26].

Conclusion

The findings indicated a strong influence of seedling age and nutrient sources on grain and stover yield of sweet corn. It was found that 22 days old seedlings and application of ½ RDF + PM recorded significantly higher values of yields. Further, it was inferred that seedling ages didn't impose any significant impact on soil physico-chemical properties and nutrient content of grain and stover. However, nutrient uptake by grain as well as stover varied significantly with the age of seedlings. On the other hand sources of nutrients imposed a significant influence on soil physic-chemical properties, nutrient content as well as nutrient uptake.

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