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Effect of integrated plant nutrient management on the quality parameters of sweet corn in a vertisol of Chhattisgarh

Jyoti Bala, LK Srivastava, VN Mishra, Jagriti Patel, Gourav Jatav and RK Banwasi

Abstract
Experiments were conducted during the year 2020-21 and 2021-22 in Rabi season at the research farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.). The field technique for conducting soil test crop response correlation studies, as described by Ramamoorthy *et al.* (1967) was followed. The treatments consisted of various combinations of nitrogen, phosphorous and potassium fertilizers at different levels of farmyard manure. It was observed that fertilizer nitrogen had the highest effect on improving the total sugar, starch and protein contents of sweet corn, which was followed by fertilizer phosphorous and potassium. Farmyard manure used in combination with the fertilizers also increased the total sugar and starch contents. However, its effect was found less in the improvement of protein contents of sweet corn. The balanced fertilization obtained was 120:60:60 kg ha^{-1} of N, P, K for total sugar and starch contents and 180:60:60 kg ha^{-1} of N, P, K at 10 t ha^{-1} FYM for protein contents.

Keywords: Soil test crop response correlation studies, total sugar content, starch content, protein content, balanced fertilization

1. Introduction

Sweet corn, known as high sugar type of maize, also known as sugar corn or pole corn, is grown for human consumption to be eaten fresh as a vegetable, rather than as a grain. Its flavour is highly dependent on the sweetness, which is determined by the amount of sugar and starch in the endosperm (Tracy, 1994) [13]. It is the result of natural occurrence of a recessive mutation in the genes which govern the conversion of sugar to starch inside the endosperm of maize kernels. The defined genes affect the synthesis of starch in seed endosperm, causing an increase in the sugar content and a decrease in starch content in the seeds. This results in a much tastier sweet in sweet corns than in regular or normal corns, specifically at 18 to 21 days after pollination. Sweet corn, generally has a total sugar content of 25-30% (Kumar *et al.* 2016) [8]. Sweet corn can prove to a better alternative crop for the areas with low rainfall and uplands and can provide lucrative returns. It has gained popularity in the urban and rural areas because of its high content of sugar (14-20%), low content of starch, vitamin A and C contents. Its fodder also provides a good market price and profitable income for the farmers. Therefore, for getting a good production or higher kernel quality of sweet corns, it is necessary to manage sweet corn in the fields properly. The main obstacle to its widespread adoption among the Indian producers is lack of proper production technologies. Like maize, sweet corn is also an exhaustive crop as it uptakes higher amount of plant nutrients from the soil. Therefore, it is essential to apply the nutrients in a balanced way and/or in an integrated way by the combination of organic and inorganic fertilizers, to replenish the nutrients in soil. Canatoy 2018 [4] have reported improvements in the green cob yield of sweet corn with the use of NPK fertilizers + organic manures applied through FYM or vermicompost. Organic manures build up the soil macrofauna and microfauna, and helps in improving the soil physical properties. It also makes available the essential nutrients to the plants at a slow rate. While, chemical fertilizers make available the essential nutrients applied to the soil at a faster rate to the plants. But the sole use of chemical fertilizers has incurred harm to the soil and environment. Therefore, integrating the chemical fertilizers with organic manures like FYM or compost can help in maintaining the soil productivity. To gain more importance and increase the productivity of sweet corn, it is therefore important to increase its productivity with the help of such technologies.

On considering the above concerns, the objective of this study was undertaken, which was to study the effect of combinations of chemical fertilizers and FYM under soil test crop response correlation studies on the quality parameters of sweet corn.

2. Materials and Methods

2.1 Details of experimental site and treatment combinations

The field experiments were conducted at the research farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, during *Rabi* season of 2020-2021 and 2021-2022. The site was characterized by sub-humid climate and 1400-1600 mm of average annual rainfall. The soil was clayey textured with dark brown to black color, typical fine montmorillonitic, hyperthermic, Udic Chromustert and it belong to the order Vertisol. The experiment was located in the east of Raipur, at 21˚ 16” N latitude and 81˚ 36” E longitude with an altitude of 298.56 meter above the mean sea level. The initial soil properties of the experiment were: pH 7.5, EC 0.21 dS m^{-1}, organic carbon 5.8 g kg^{-1}, available N 224 kg ha^{-1}, available P 18.9 kg ha^{-1} and available K 495 kg ha^{-1}.

The field experiments were laid out as per the technique given by Ramamoorthy *et al.* (1967) [11] of the All India Coordinated Research project for Investigation on Soil Test-Crop Response Correlation (STCR). The field was divided into three fertility strips: L_0, L_1 and L_2, where no GRD (general recommended dose of fertilizers), full GRD and double GRD was applied, and the exhaust crop (fodder maize) was grown. GRD applied were 100:60:40 kg ha^{-1} of N, P_2O_5 and K_2O fertilizers. After the harvest of the exhaust crop, each fertility strip was divided into three blocks unto which each block consisted of 7 treatments + 1 control (plot-wise), thus resulting into a total of 21 treatments + 3 control. Therefore, the total treatment combinations in the experiment were 72. The test crop taken was sweet corn var. Sugar-75. The details of the treatment combinations are given in Table 1. The treatments consisted of 4 levels each of N (0, 60, 120, 180 kg ha^{-1}), P_2O_5 (0, 30, 60, 90 kg ha^{-1}) and K_2O (0, 30, 60, 90 kg ha^{-1}) fertilizers along with the combinations of 0, 5 and 10 t ha^{-1} of FYM (which were imposed across the strips block-wise). The source of fertilizers was Urea, Diammonium Phosphate (DAP) and Muriate of Potash (MOP). Phosphorous and potassium fertilizers were applied at the time of sowing, while nitrogen fertilizer was applied as basal and then at the four-leaf, eight leaf and tasseling stage of the crop. The test crop was sown at a spacing of 70×20 cm. in each plots having size 5m×4m = $20m^2$.

Table 1: Treatment combinations in each fertility strip: 21 + 3 Control

A	B	C
T_1: 120:90:90	T_9: 0:0:0	T_{17}: 120:60:90
T_2: 180:90:90	T_{10}: 120:90:60	T_{18}: 120:0:60
T_3: 0:0:0	T_{11}: 180:30:30	T_{19}: 180:60:30
T_4: 0:60:60	T_{12}: 180:60:60	T_{20}: 0:0:0
T_5: 180:90:30	T_{13}: 120:30:60	T_{21}: 60:60:30
T_6: 180:90:60	T_{14}: 60:60:60	T_{22}: 60:30:30
T_7: 60:30:60	T_{15}: 120:60:0	T_{23}: 120:30:30
T_8: 180:60:90	T_{16}: 120:60:60	T_{24}: 120:60:30

2.2 Analysis of quality parameters

2.2.1 Preparation of samples

The parameters taken for quality analysis were total sugar content, starch content and protein content in the kernels of sweet corn. For total sugar and starch content, kernels were removed from the selected cobs from each plot and taken to the refrigerator to be stored at -18 °C for stopping further metabolic activity in the kernels. For protein contents, the kernels removed from the cobs from each plot were oven dried for 48 hours and then put for grinding. Therefore, protein contents of the kernels were determined on dry-weight basis.

2.2.2 Moisture content (%)

Grain samples (or kernels) removed from the cobs were weighed fresh at the time of sampling and kept in aluminum boxes for oven drying at 80 °C. The oven dried samples were weighed and the moisture content in grain samples were determined by using the following formula:

$$\text{Moisture content (\%)} = \frac{FW-DW}{FW} \times 100$$

Where, fresh weight of the grain samples is denoted as FW, and dry weight of the grain samples is denoted as DW.

2.2.3 Total Sugar content (%) and starch content (%)

For conducting the analysis, fresh grain samples were taken and grinded using mortar and pastel. A 15 ml centrifuge tube was taken and 100 mg of the grinded samples were put and 10 ml of 80% ethanol was added in it. The tubes were then kept in water bath at 80-85 °C for 30 min. and then centrifuged. The supernatant was put into a 50 ml beaker. This procedure was repeated three more times (Hedge and Hofreiter, 1962) [6].

For the estimation of total sugar content, the supernatant was evaporated by keeping it on a water bath at 80-85 °C until most of the alcohol is removed. The extract was then put in a 25 ml volumetric flask and the volume was made up with distilled water. 5 ml of this diluted extract was put in a 100 ml volumetric flask and the volume was made up with distilled water. 5 ml from the preceding diluted extract were taken in a Pyrex test tube and the tubes were kept in an ice bath. 10 ml of anthrone reagent prepared by dissolving 200 mg anthrone in a 100 ml of ice cold 95% H_2SO_4, was added slowly to the test tubes. The tubes were then put in a boiling water bath for exactly 7.5 min. and then immediately cooled in ice. The absorbance was then measured at 630 nm with the help of a spectrophotometer. Calculation of total sugar content was done by creating a curve against standard glucose and total sugar content was expressed in percent (%).

For starch estimation, the residue left after centrifugation in the first step of sample preparation was oven dried at 80 °C. To the sample 2ml of distilled water was added and put in a water bath for 15 min. with continuous stirring. The sample was allowed to cool and 2ml of 9.2 N $HClO_4$ was added with constant stirring for 15 min. The suspension was then made up to 10 ml with distilled water and put for centrifugation. The supernatant was collected in a 50 ml volumetric flask. To the residue left in the centrifuge tube, 2 ml of 4.6 N $HClO_4$ was added with constant stirring for 15 min. and 10 ml of distilled water was added. It was again centrifuged and the supernatant collected. Both the supernatants were combined and put in a 50 ml volumetric flask and volume was made up with distilled water. 5 ml of this extract was taken in a 50 ml volumetric flask and volume was made up with distilled water. 5 ml of this diluted extract was taken in Pyrex test tube and the tubes were kept in an ice bath with slow addition of 10 ml anthrone reagent. The tubes were then put in water bath for 7.5 min. and then immediately cooled. The starch extracted was measured in a spectrophotometer at absorbance 630 nm. For calculating the starch content, the concentration was calculated by plotting a curve against standard glucose and multiplying it by a factor of 0.9.

2.2.4 Protein content (%)

Total nitrogen (N) content (%) in kernels were determined by Kjeldahl method, as described by Chapman and Pratt (1961) [5] on dry weight basis. The protein contents were then determined by multiplying 6.25 to the total N content of kernels (Tsen and Martin, 1971) [14].

3. Results and Discussion

3.1 Effect of integrated nutrient management on the moisture content, total sugar, starch and protein content of sweet corn kernels

Sweet corn is known for its higher sugar content at the time of milky stage, i.e., at the time of harvest of its green cobs. This determines its market quality. However, the sugar in sweet corn kernels, after a short while gets converted to starch. Therefore, in this study the total sugar and starch content were estimated at the time of milky stage of the crop.

Mean values of moisture content (%) in sweet corn kernels recorded during 2020-21 were 78.4% in L_0 strip, 78.6% in L_1 strip and 77.1% in L_2 strip, respectively (Table 2). However, during 2021-22, the mean values were 78.6% in L_0 strip, 79.9% in L_1 strip and 78.5% in L_2 strip, respectively (Table 2).

Total sugar content in L_0 strip varied from 8.1-11.2% with a mean of 9.9% for the year 2020-21, and 8.5-11.8% with a mean of 10.4% for the year 2021-22 (Table 2). However, the sugar contents were 8.6-12.2% with an average of 10.2% and 9.2-12.9% with an average of 10.8% in L_1 strip for both the cropping years. It varied from 8.9-12.0% with an average of 10.3%, and 9.5-12.7% with a mean of 11% in L_2 strip for both the cropping years (Table 2). This showed that there were no marked variations in sugar content with respect to the fertility gradient created. Similar sugar contents were reported by Pairochteerakul *et al*., 2018 [10] in sugar-75 variety of sweet corn.

Starch contents varied from 4.2-6.3% with a mean of 5.2%, and 4.4-6.6% with a mean of 5.5% in L_0 strip during 2020-21 and 2021-22 (Table 2). In L_1 strip, the values ranged from 4.4-6.2% with a mean of 5.3%, and 4.7-6.7% with a mean of 5.7% during both cropping years. However, in L_2 strip, it varied from 4.5-6.2% with a mean of 5.5%, and 4.8-6.7% with a mean of 5.9% for both the cropping years (Table 2). Similar starch contents were reported by Pairochteerakul *et al*., 2018 [10] in sugar-75 variety of sweet corn. Lower contents of starch might be due to the lower synthesis of starch and higher accumulation of sugar during milky stage of the crop (Boyer *et al*., 2001) [3].

The mean values of protein content during both the cropping years were 7.7 and 7.9% in L_0 strip, 7.9 and 8.1% in L_1 strip, and 8.3 and 8.5% in L_2 strip, respectively (Table 2). It was observed that the values of protein content increased from L_0 to L_2 strip. However, the variations were not highly marked. Similar results were obtained by Saracoglu and Oktem, 2021 [12] in maize. Higher protein contents in L_2 strip might be due to more N availability from soil for protein synthesis.

The response of different levels of fertilizer N, P, K and FYM on total sugar, starch and protein content at milky stage of the crop was observed. It was recorded that the total sugar, starch and protein contents increased with increasing the fertilizer N levels. The different levels of fertilizer N contributed 60 and 59% (coefficient of determination, R^2 = 0.60 and 0.59) variation on the total sugar contents (Fig. 1) and 71 and 68% (R^2 = 0.71 and 0.68) variation (Fig. 3) on the starch contents of sweet corn during both the cropping years. Similar results of increased sugar and starch content with increasing the levels of fertilizer N were reported by Bharathi *et al*., 2020 [2]. Further, the different levels of fertilizer N contributed 76 and 73% (R^2 = 0.76 and 0.73) variation on the protein content of sweet corn (Fig. 5). Similar results of increase in protein content of corn kernels with increasing N levels were reported by Saracoglu and Oktem, 2021 [12] in maize. This might be due to the higher N availability in the soil with increase in N levels, which resulted in more accumulation of assimilates (sugar, starch and protein contents) in the sink (sweet corn kernels).

The variability due to different levels of fertilizer P was 44% (R^2 = 0.44) on the total sugar contents (Fig. 2); 47 and 45% (R^2 = 0.47 and 0.45) on starch contents (Fig. 4), and 38 an 39% (R^2 = 0.38 and 0.39) on the protein content (Fig. 6) of sweet corn kernels during both the cropping years. The lower variation on total sugar, starch and protein content due to fertilizer P might be due to the lower availability of P in soil, as the fertilizer P after its application to the field gets fixed in the soil after some time, due to its reaction with inorganic compounds present in the soil. The variability due to fertilizer K and FYM on the total sugar, starch and protein contents were found less than 30% ($R^2 < 0.30$) for both the cropping years.

Regression analysis (based on the average values of two cropping years) was also performed to determine the relationship between the applied fertilizer nutrients and FYM with the total sugar, starch and protein contents of sweet corn kernels to check the goodness of fit of the data set (Table 3). It was observed that fertilizer N contributed highest variation on the total sugar (R^2 = 0.60), starch (R^2 = 0.70) and protein contents (R^2 = 0.75) of sweet corn kernels, followed by fertilizer P and K and the lowest contribution was of FYM (Equation 1-4, 13-16 and 25-28). However, when FYM was used in combination with the fertilizers, it improved the contribution on sugar and starch contents (Eq. 9-12 and 21-24). This indicates that integrating fertilizers with FYM can prove to be beneficial in improving the total sugar and starch contents of sweet corn. This might be due to the greater availability of essential nutrients in the root zone of sweet corn, caused by solubilization of nutrients by the organic acids produced by FYM during its decomposition in the soil, thereby causing an increased uptake of nutrients by sweet corn, enhancement of photosynthetic and metabolic activity, resulting in better partitioning of photosynthates to sinks, which got reflected in the improvement of total sugar and starch contents in sweet corn kernels. Further, the effect of FYM with fertilizer NPK on protein content did not contribute much variations (Eq. no. 32; R^2 value of 0.78) as compared with the application of fertilizer NPK alone (Eq. no. 33; R^2 value of 0.77). It was observed that there were no improvement on the variability of protein contents due to the addition of FYM with fertilizers (Eq. no. 34-36) as compared to the fertilizer applications alone (Eq. no. 25-27). Therefore, for improving the protein contents in sweet corn kernels, FYM did not prove much beneficial as compared to the application of fertilizers.

The effect of different levels of fertilizer N, P and K at varying levels of FYM on the total sugar and starch contents of sweet corn was also computed (Fig. 7 and 8). It was observed that the total sugar and starch contents increased upto 120:60:60 kg ha^{-1} of N, P, K at different levels of FYM (especially under 10 t ha^{-1} FYM) and then it started decreasing or reached its plateau maximum (Fig. 7 and 8). Similarly, Kamalakumari and Singaram (1996) [7] have reported that total sugars and starch contents improved under the application of 100:40:40 kg N, P_2O_5 and K_2O with 10 t ha^{-1} FYM as compared to other treatments. Arunkumar *et al.* (2007) [1] have also reported that RDF (112.5 + 75 + 37.5 kg N, P, K ha^{-1}) increased the total sugars of sweet corn, and reducing N below 75% and P and K below 100% of RDF decreased the total sugar contents. Therefore, according to our study, 120-60-60 kg ha^{-1} of N, P, K at 10 t ha^{-1} FYM can give balanced fertilization to sweet corn with respect to its total sugar and starch content. However, the effect of different levels of fertilizer N, P and K at varying levels of FYM on the protein content of sweet corn revealed that the protein contents increased upto 180 kg N ha^{-1}, 60 kg P ha^{-1} and 60 kg K ha^{-1} (Fig. 9), which indicates the balanced dose for obtaining the highest content of protein in sweet corn kernels for our study. Similarly, Oktem *et al*. (2010) [9] reported that the protein content in sweet corn kernels increased with increasing levels of N (upto 360 kg ha^{-1}) with the application of 38.6 kg P_2O_5 ha^{-1} and 40 kg K_2O ha^{-1}.

Table 2: Quality parameters in sweet corn kernels during *Rabi* season, 2020-21 and 2021-22

Sweet corn	Fertility Strips	Sugar content (%)	Starch content (%)	Moisture content (%)	Protein Content (%)
2020-21	L_0 (Mean)	8.1-11.2 (9.9)	4.2-6.3 (5.2)	68.7-81.3 (78.4)	6.2-8.7 (7.7)
	L_1 (Mean)	8.6-12.2 (10.2)	4.4-6.2 (5.3)	77.1-79.4 (78.6)	6.5-8.9 (7.9)
	L_2 (Mean)	8.9-12.0 (10.3)	4.5-6.2 (5.5)	73.7-79.2 (77.1)	6.6-9.2 (8.3)
	Mean	10.2	5.3	78.04	8.0
2021-22	L_0 (Mean)	8.5-11.8 (10.4)	4.4-6.6 (5.5)	68.8-81.5 (78.6)	6.3-8.9 (7.9)
	L_1 (Mean)	9.2-12.9 (10.8)	4.7-6.7 (5.7)	78.3-80.6 (79.9)	6.6-9.1 (8.1)
	L_2 (Mean)	9.5-12.7 (11.0)	4.8-6.7 (5.9)	75.1-80.7 (78.5)	6.8-9.6 (8.5)
	Mean	10.7	5.7	79.0	8.2

Table 3: Multiple linear regression analysis performed for determining the relationship of applied fertilizer nutrients and FYM on total sugar, starch and protein content of sweet corn kernels

S. No.	Regression models	R^2
	Sugar content (%)	
1.	Y = 9.14 + 0.012 FN	0.60
2.	Y = 9.35 + 0.022 FP	0.44
3.	Y = 9.80 + 0.014 FK	0.17
4.	Y = 10.23 + 0.044 FYM	0.03
5.	Y = 8.93 + 0.009 FN + 0.011 FP	0.67
6.	Y = 9.30 + 0.021 FP + 0.002 FK	0.44
7.	Y = 9.08 + 0.012 FN + 0.003 FK	0.61
8.	Y = 8.95 + 0.009 FN + 0.011 FP – 0.001 FK	0.67
9.	Y = 8.92 + 0.012 FN + 0.044 FYM	0.64
10.	Y = 9.13 + 0.022 FP + 0.044 FYM	0.48
11.	Y = 9.58 + 0.014 FK + 0.044 FYM	0.20
12.	Y = 8.73 + 0.009 FN + 0.011 FP – 0.001 FK + 0.044 FYM	0.70
	Starch content (%)	
13.	Y = 4.69 + 0.008 FN	0.70
14.	Y = 4.86 + 0.013 FP	0.46
15.	Y = 5.03 + 0.011 FK	0.28
16.	Y = 5.38 + 0.03 FYM	0.04
17.	Y = 4.57 + 0.0062 FN + 0.0058 FP	0.76
18.	Y = 4.60 + 0.007 FN + 0.004 FK	0.73
19.	Y = 4.77 + 0.011 FP + 0.004 FK	0.50
20.	Y = 4.54 + 0.006 FN + 0.005 FP + 0.002 FK	0.76
21.	Y = 4.54 + 0.008 FN + 0.03 FYM	0.74
22.	Y = 4.71 + 0.013 FP + 0.03 FYM	0.51
23.	Y = 4.88 + 0.011 FK + 0.03 FYM	0.32
24.	Y = 4.39 + 0.006 FN + 0.005 FP + 0.002 FK + 0.03 FYM	0.81
	Protein content (%)	
25.	Y = 6.92 + 0.011 FN	0.75
26.	Y = 7.26 + 0.016 FP	0.39

27.	Y = 7.44 + 0.014 FK	0.26
28.	Y = 8.06 + 0.005 FYM	0.0006
29.	Y = 6.82 + 0.010 FN + 0.005 FP	0.77
30.	Y = 6.82 + 0.0099 FN + 0.0043 FK	0.76
31.	Y = 7.13 + 0.013 FP + 0.007 FK	0.43
32.	Y = 6.78 + 0.0092 FN + 0.0035 FP + 0.003 FK	0.77
33.	Y = 6.76 + 0.0092 FN + 0.0035 FP + 0.003 FK + 0.005 FYM	0.78
34.	Y = 6.9 + 0.011 FN + 0.005 FYM	0.75
35.	Y = 7.24+ 0.016 FP + 0.005 FYM	0.39
36.	Y = 7.42 + 0.014 FK + 0.005 FYM	0.26

Where, FN is fertilizer nitrogen (kg ha^{-1}), FP is fertilizer phosphorous (kg ha^{-1}), FK is fertilizer potassium (kg ha^{-1}), Y represents dependent variables (sugar and starch contents), FYM is farm yard manure (t ha^{-1}). Values were significant at 5% probability level.

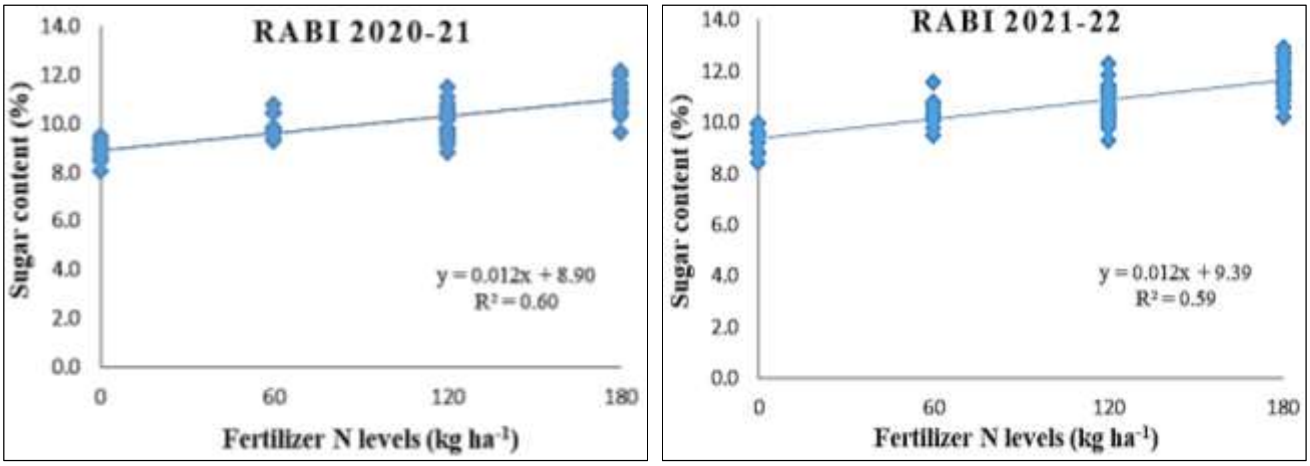


Fig 1: Response of different levels of fertilizer N on total sugar content of sweet corn kernels

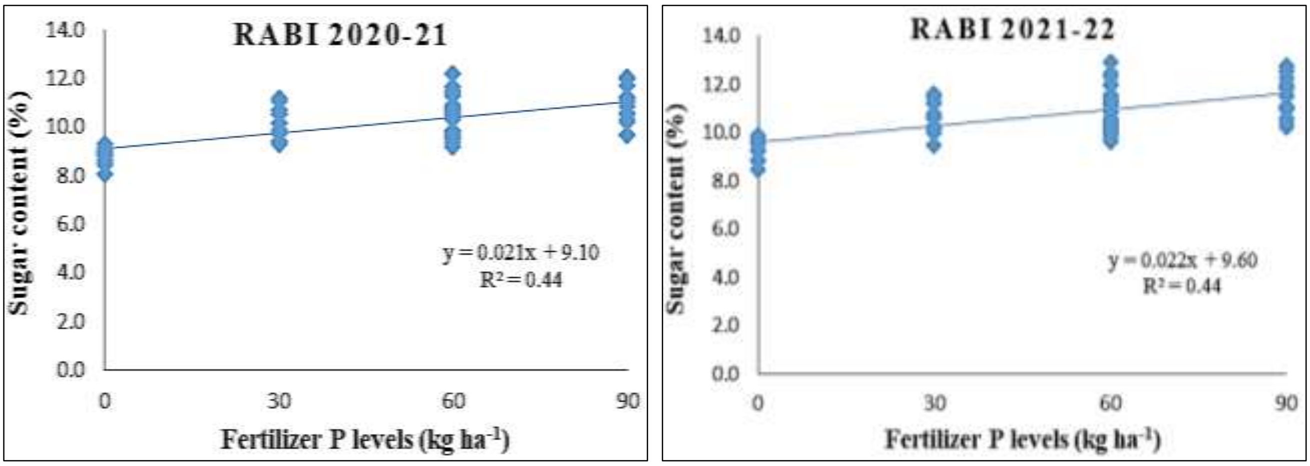


Fig 2: Response of different levels of fertilizer P on total sugar content of sweet corn kernels

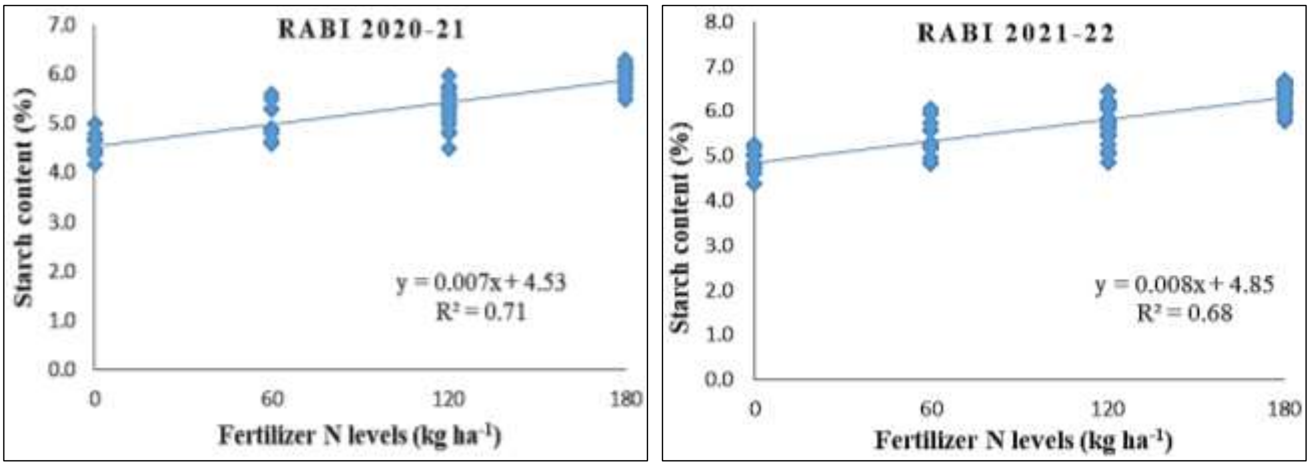


Fig 3: Response of different levels of fertilizer N on starch content of sweet corn kernels

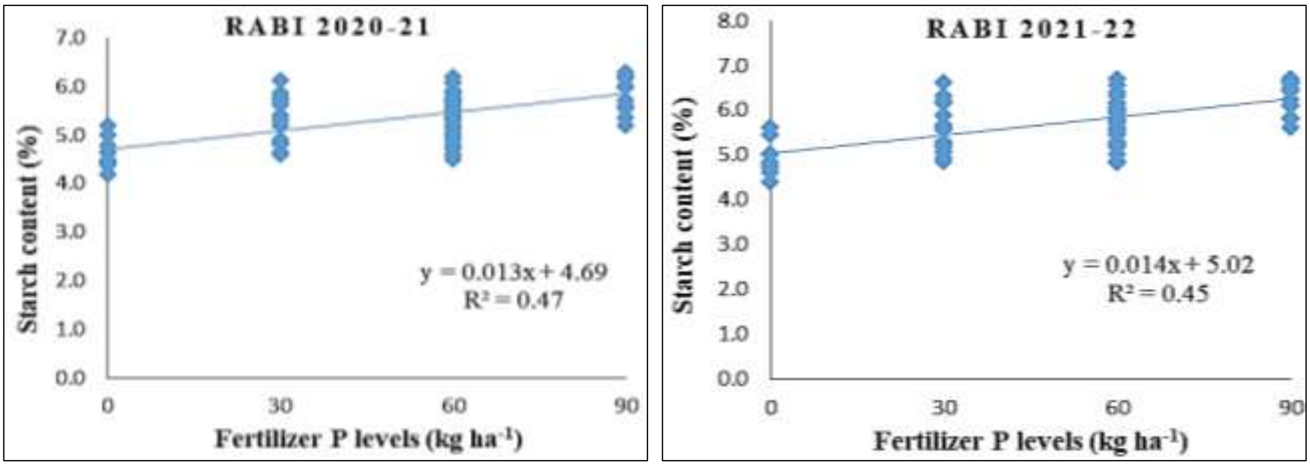


Fig 4: Response of different levels of fertilizer P on starch content of sweet corn kernels

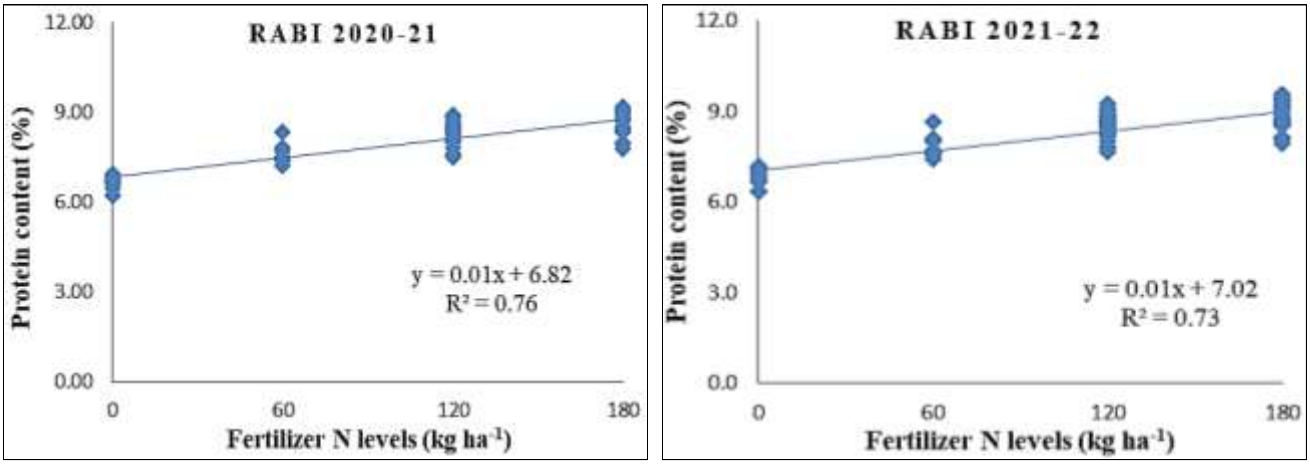


Fig 5: Response of different levels of fertilizer N on protein content of sweet corn kernels

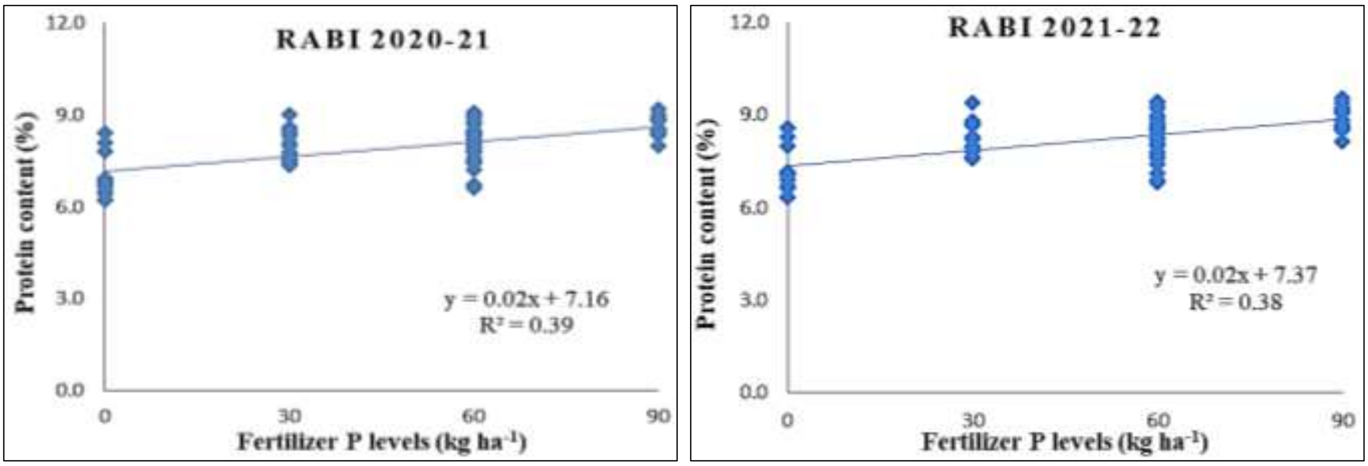


Fig 6: Response of different levels of fertilizer P on protein content of sweet corn kernels

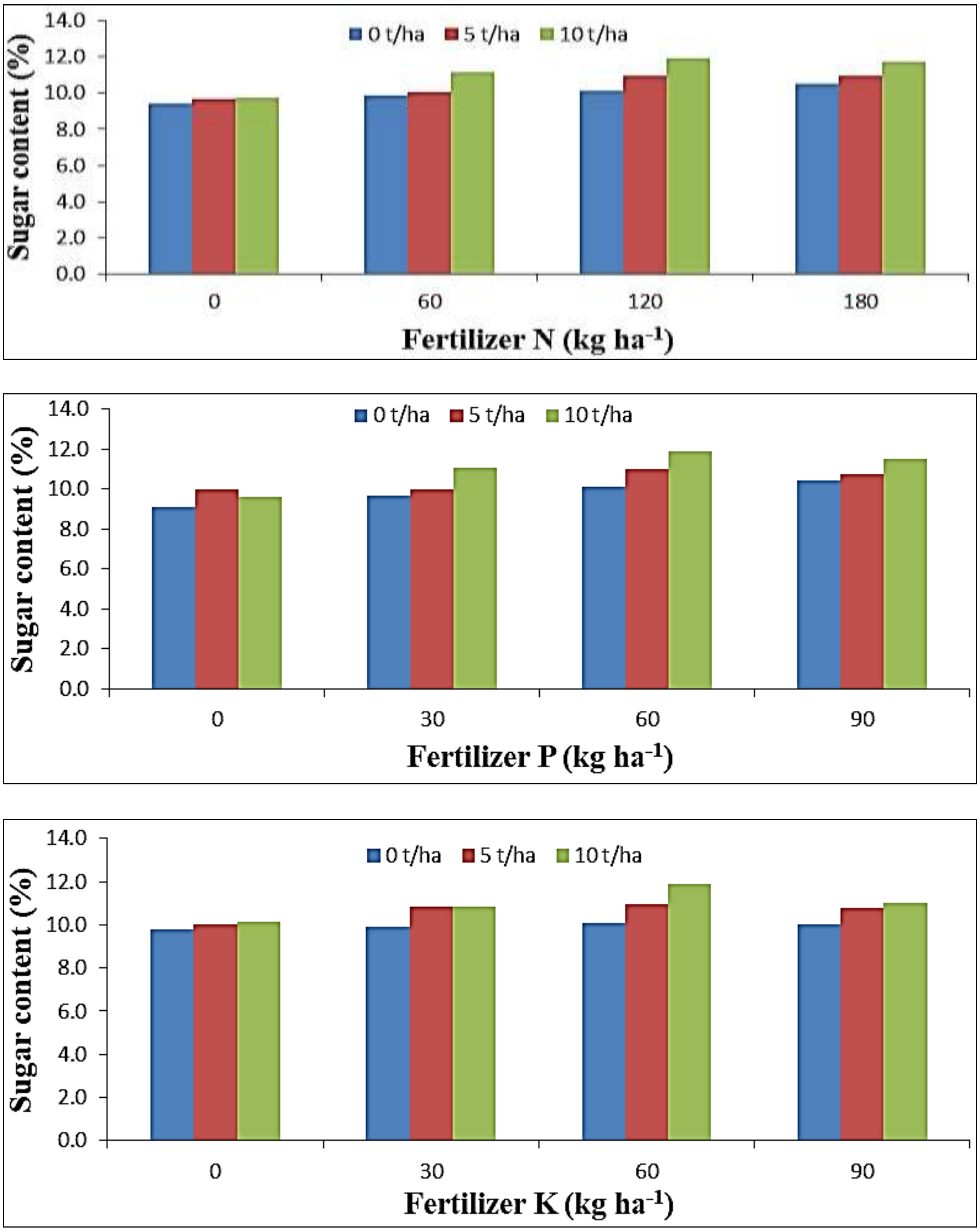


Fig 7: Sugar content (%) in sweet corn kernels as affected by fertilizer N, P_2O_5 and K_2O at varying levels of FYM

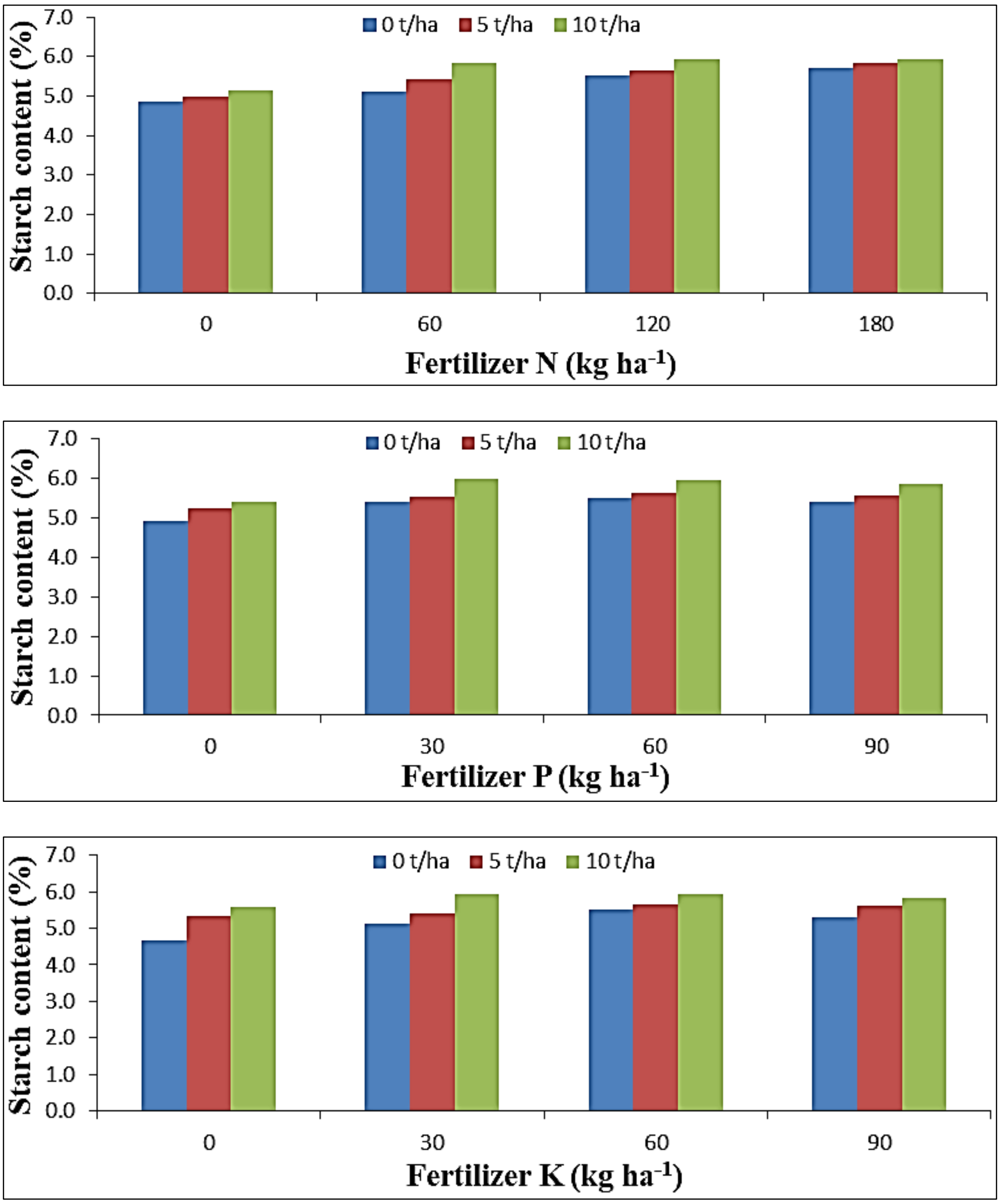
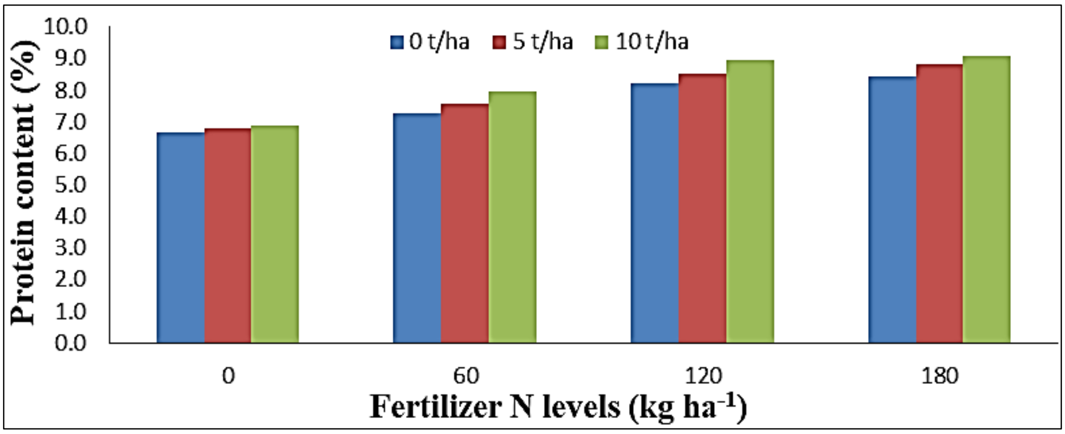


Fig 8: Starch content (%) in sweet corn kernels as affected by fertilizer N, P_2O_5 and K_2O at varying levels of FYM



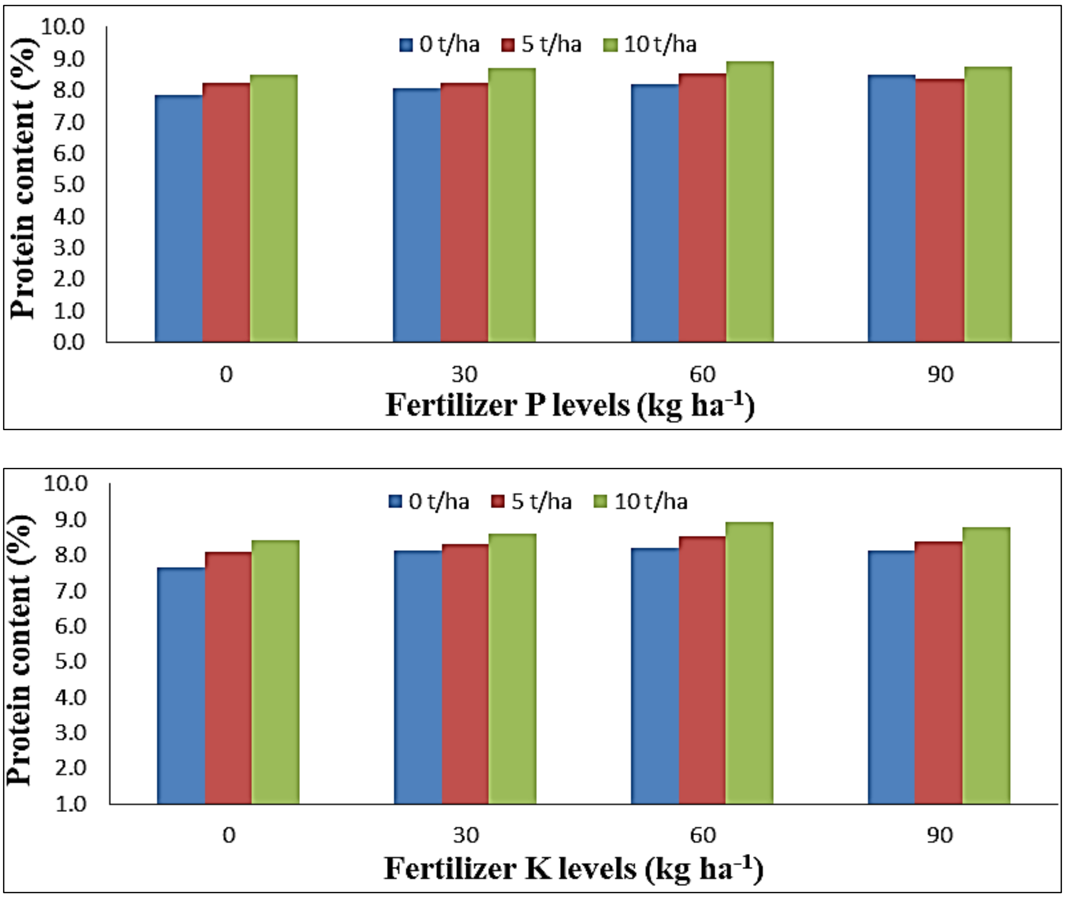


Fig 9: Protein content (%) in sweet corn kernels as affected by fertilizer N, P_2O_5 and K_2O at varying levels of FYM

4. Conclusion

Fertilizer N had the highest effect on total sugar, starch and protein contents of sweet corn kernels, followed by fertilizer P and K, and the lowest was contributed by FYM. However, when FYM was used in combination with the fertilizers, it increased the variation on total sugar and starch contents. This indicates that integrating fertilizers with FYM can help in improving the total sugar and starch contents of sweet corn. But, FYM in combination with the fertilizers had not increased the protein content of sweet corn kernels. 120-60-60 kg ha^{-1} of N, P, K at 10 t ha^{-1} FYM, and 180-60-60 kg N, P and K ha^{-1} at 10 t ha^{-1} FYM proved to be the balanced dose for sweet corn with respect to its total sugar, starch and protein contents.

5. References

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