Management of low nitrogen input with potassium and phosphorus fertilizers for cropping system and yield of Sweet Sorghum Crop (Sorghum bicolor L. Moench) in a field experiment at Panskura, East Midnapore, West Bengal

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ABSTRACT
A plot experiment was supervised in open pollinated field to evaluate the response of lower doses of Nitrogen combined with standard to high potassium and Phosphorus doses and the relative effects on sweet sorghum (Sorghum bicolor L. Moench) yield in Panskura Agriculture Field located at East Midnapore of West Bengal during 2017-18 in a randomized block design (RBD) with three replications. Data were collected on every 30 days interval starting from 40 Days After Sowing (DAS) to 130 DAS. Results revealed that maximum plant height of 193.4 cm was observed in N, P, K treatment at 130 DAS, maximum green biomass of 26.84 t/ha was observed with N, P, K treatment at 100 DAS, maximum sugar concentration of 10.07 % was observed with N, P, K treatment at 100 DAS and highest sugar yield of 1896.88 kg/ha with the same ratio of fertilizer treatment. All the parameters were evaluated to identify the cost-effective status as well as the significance of the study.

Key words: Nitrogen, Plant height, Phosphorus, Potassium, Sugar percentage, Sugar yield, Sweet sorghum.

INTRODUCTION
Sorghum [Sorghum bicolor (L.) Moench], has been well received from over 150 years for providing high quality dense carbohydrate sap, animal fodder, herbage and cuisine (Schaffert,1988 ; Grassi,2001). Vast range adaptive nature in moisture shortage environment (Reddy et al. 2005; Zegada-Lizarazu et al.2012) and rewarding large quantity of fit state fermentable sugar (Szakal et al.2007; Reddy et al.2005) lead this energy crop in exaggerated demands. The sugar constituent correspondingly increases to the maturing phases in sweet sorghum and catch up to its great vertical extent at highest stem growth stage (Parvatikar and Manjunath, 1991) which enlightens a relationship between total carbohydrate content and stages of growth (Viertor, et al.1990; Zhao, et al.2009). Proper cropping system of sweet sorghum as well as the quality growth of this plant demands for balanced and wise inputs of fertilizers exogenously in various fields of West Bengal (Barik et al. 2015 and 2017; Roy et al, 2016 and 2018).

Nitrogen use efficiency (NEU) of sorghum (C4 crop) is admitted by many research studies and reported to be more efficient than many C3 plants (Gardner et al.1994; Anten et al.1995). Depending on soil fertility, Zhao et al. (2005), addressed a range of 45 to 224 kg N ha\(^{-1}\) application for the sorghum farmers. However, peak doses of N fertilizer should be inhibited since excessive N may cut down crop ethanol yield (Wiedenfeld,1984) as well as considerably enhance production costs and reduce energy efficiency, in reflection of the fact that N fertilization scores up to 50% of the total energy input in arable cropping system (Kuesters and Lammel,1999). Nevertheless, there are some adverse outcomes of inappropriate N implication. Using high amount of N fertilizer in cultivation can result in contamination of groundwater (Jaynes et al.2001) and considerably affects and disturbs sorghum leaf area index (Locke and Hons,1988). Over use of N fertilizer, moreover, imbalances soil pH environment for the crop (Munck, 1958) resulting proton release can acidify the root vicinity (Marschner and Römheld,1983 and Schaller et al.1985).

Sorghum cultivars require a greater amount of phosphorus for initial growth and development and for expressing properly their yield potential. Lower application dose of phosphorus in respect to nitrogen has been proven as one of the prior parameters limiting better crop yield (Chaubey et al.1992). Significant effects of phosphorus on sorghum on focusing of the properties as water stress condition, higher yield issue and better sustainability with efficient utilization of Phosphorus input were reported by many scientific studies (Cisar et al.1992; Singaram and Kothar’Idaraman, 1994). A significant influence of potassium (K) on sorghum growth was analysed by Sharma and Ramma (1993).In water stress condition potassium plays an important role modulating supportively the physiology parameters of sorghum (Sharma and Kumari,1996).

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Our study has been undertaken with a goal to use moderate to less amount of application of nitrogen fertilizer and compensate the input balance by combining phosphorus and potassium fertilizers in a variable manner on sweet sorghum in open pollinated favourable climatic condition. The evaluation of yield efficiency is determined by collecting data with a repeated method in respect to parameters such as its plant height, sugar content, sugar percentage and fresh green biomass, etc. and thus the dose combinations are analysed.

MATERIALS AND METHODS

The research experiment was performed in 2017-18 at Panskura Agriculture Field, East Midnapore, West Bengal. Soil texture of East Midnapore is mainly alluvial coastal type. The organic carbon is medium to high and phosphate as well as the potash content is low, and pH ranges between 6 and 7 (slightly acidic or neutral). Sweet sorghum variety SSV-84 was collected from Indian Institute of Millets Research (IIMR) Rajendranagar (Telangana, India). The experiment was arranged in a random way by designing blocks (3×2×3) where total treatment combinations were eighteen (18) with three (3) replications and each plot measuring 12 m² (4m×3m). Row to row 45 cm and plant to plant 15 cm spacings were maintained. The size of each plot was 12 Sq. m (4m×3m) with a Plant Population of 96 /Plot (12×8) were designed. Three doses of nitrogen (0 (N), 50 (N), and 100 (N) Kg/ha) were applied by mean of urea fertilizer (46% N). Three levels of potassium (0 (K), 50 (K), and 100 (K) Kg/ha) were applied as muriate of potash (60% K). Two levels of phosphorous (0 (P), 60 (P) Kg/ha) were applied as Single Super Phosphate (16%P). All fertilizers were applied as basal dose except nitrogen. Half of the nitrogen was applied as basal and another half as top dressing at the 30th days after sowing (DAS). Data were collected at every 30 days interval starting from 40 DAS (Days After Sowing) up to 130 DAS. The research experiment was started from 19/10/2017 and maintained up to 27/02/2018. Randomly ten plants selected were collected from each treatment for measuring its growth and other parameters such as plant height, green biomass, sugar concentration, and sugar yield from four different harvests. Plant height data (186.78 cm) at 130 DAS. This result indicates that increase of nitrogen application caused increase of plant height, which follows similar results reported as that of

RESULTS AND DISCUSSION

Effect on plant height (cm): The effect for individual doses of applied nitrogen, potassium and phosphorus on plant height were significantly different from each other (Table 1). In case of nitrogen, N₁ (100 kg/ha) gave the highest plant height data (186.78 cm) at 130 DAS. This result indicates that increase of nitrogen application caused increase of plant height, which follows similar results reported as that of

Table 1: Plant height (cm) at various growth stages of sweet sorghum by different fertilizer doses.

| PLANT HEIGHT | 40 DAS | 70 DAS | 100 DAS | 130 DAS |
|--------------|--------|--------|---------|---------|
| **TREATMENT** |        |        |         |         |
| **NITROGEN** |        |        |         |         |
| N₀          | 59.8   | 69     | 74.42   | 6.97    |
| N₁          | 122.19 | 131.13 | 137.91  | 0.72    |
| SE          | 1.42   | 1.46   | 1.554   | 3.41    |
| LSD         |        |        |         |         |
| **PHOSPHORUS** |        |        |         |         |
| P₀          | 62.07  | 73.41  | 70.31   | 6.97    |
| P₁          | 123.82 | 137    | 132.98  | 0.72    |
| SE          | 1.15   | 0.57   | 0.57    | 1.37    |
| LSD         | 1.19   | 1.27   | 1.554   | 3.41    |
| **INTERACTION** |        |        |         |         |
| N₀ P₀       | 54.09  | 55.39  | 58.98   | 62.52   |
| N₀ P₁       | 65.67  | 67.78  | 71.08   | 71.81   |
| N₁ P₀       | 65.75  | 71.87  | 134.77  | 71.81   |
| N₁ P₁       | 67.31  | 72.70  | 130.23  | 72.70   |
| SE          | 0.87   | 0.62   | 1.27    | 1.27    |
| LSD         | 1.37   | 1.27   | 3.41    | 3.41    |

Sugar yield per hectare was worked out using the formula

\[ \text{Sugar Yield (Kg/ha): Sugar yield} = \left\{ S - 0.4 \times (B - S) \right\} \times F \times Y/100 \]

All doses were applied in combinations ratio and results were judged with respect to the control of each dose. All the data were statistically analyzed using Analysis of Variance technique as described by Gomez and Gomez (1984).

Calculated sugar yield (t/ha): Sugar yield = \( \left( S - 0.4 \times (B - S) \right) \times F \times Y/100 \). All doses were applied in combinations ratio and results were judged with respect to the control of each dose. All the data were statistically analyzed using Analysis of Variance technique as described by Gomez and Gomez (1984).
Salvatore et al. (2012) but they also proposed that yield was less sensitive to N level. In case of potassium level K$_2$ (100 kg/ha) the highest plant length was observed 177.84 cm at 130 DAS. On the other hand, dose of phosphorus P$_1$ (60 Kg/ha) showed better plant height rather than null application of phosphorus. In case of combined application of N, P, K and interaction effects between nitrogen, phosphorus and potassium was found significant and the treatment N$_1$K$_3$P$_3$ gave the highest length (193.4 cm). The rate of increase in plant height from 40 DAS to 70 DAS, 70 DAS to 100 DAS and 100 DAS to 130 DAS was noticeably decreased.

**Effect on green biomass (ton/ha):** The results indicated that the effect of green biomass on individual doses of nitrogen, potassium, and cultivars were significantly different

Table 2: Green biomass (t/ha) at various growth stages of sweet sorghum by different fertilizer doses.

| PLANT GREEN BIOMASS | TREATMENT | 40 DAS | 70 DAS | 100 DAS | 130 DAS |
|---------------------|-----------|--------|--------|---------|---------|
| **NITROGEN** | | | | | |
| N$_1$ | 14.98 | 19.47 | 25.9 | 24.71 |
| N$_2$ | 15.27 | 19.75 | 26.34 | 25.09 |
| N$_3$ | 15.42 | 20.11 | 26.68 | 25.54 |
| SE | 0.008 | 0.008 | 0.009 | 0.007 |
| LSD | 0.016 | 0.016 | 0.018 | 0.015 |
| **POTASSIUM** | | | | | |
| K$_1$ | 15.18 | 19.69 | 26.21 | 24.99 |
| K$_2$ | 15.32 | 19.78 | 26.32 | 25.1 |
| K$_3$ | 15.42 | 19.86 | 26.39 | 25.25 |
| SE | 0.008 | 0.008 | 0.009 | 0.007 |
| LSD | 0.016 | 0.016 | 0.018 | 0.015 |
| **PHOSPHORUS** | | | | | |
| P$_1$ | 15.23 | 19.67 | 26.22 | 24.9 |
| P$_2$ | 15.38 | 19.88 | 26.39 | 25.33 |
| SE | 0.007 | 0.007 | 0.007 | 0.006 |
| LSD | 0.013 | 0.013 | 0.015 | 0.012 |
| **INTERACTION** | | | | | |
| N$_1$P$_1$K$_1$ | 14.82 | 19.34 | 25.75 | 24.36 |
| N$_1$P$_2$K$_1$ | 14.98 | 19.39 | 25.81 | 24.48 |
| N$_1$P$_3$K$_1$ | 15.04 | 19.46 | 25.89 | 24.54 |
| N$_1$P$_3$K$_2$ | 15.13 | 19.56 | 26.13 | 24.77 |
| N$_1$P$_3$K$_3$ | 15.2 | 19.65 | 26.26 | 24.85 |
| N$_1$P$_3$K$_3$ | 15.28 | 19.71 | 26.33 | 24.96 |
| N$_1$P$_3$K$_3$ | 15.45 | 19.86 | 26.48 | 25.13 |
| N$_1$P$_3$K$_3$ | 15.53 | 19.97 | 26.62 | 25.27 |
| N$_1$P$_3$K$_3$ | 15.67 | 20.05 | 26.68 | 25.72 |
| N$_1$P$_3$K$_3$ | 14.89 | 19.41 | 25.88 | 24.89 |
| N$_1$P$_3$K$_3$ | 15.07 | 19.52 | 25.99 | 24.94 |
| N$_1$P$_3$K$_3$ | 15.11 | 19.67 | 26.07 | 25.04 |
| N$_1$P$_3$K$_3$ | 15.22 | 19.77 | 26.3 | 25.26 |
| N$_1$P$_3$K$_3$ | 15.33 | 19.85 | 26.47 | 25.33 |
| N$_1$P$_3$K$_3$ | 15.45 | 19.93 | 26.54 | 25.38 |
| N$_1$P$_3$K$_3$ | 15.56 | 20.17 | 26.7 | 25.55 |
| N$_1$P$_3$K$_3$ | 15.83 | 20.27 | 26.76 | 25.75 |
| N$_1$P$_3$K$_3$ | 15.95 | 20.32 | 26.84 | 25.83 |
| SE | 0.02 | 0.02 | 0.022 | 0.018 |
| LSD | 0.04 | 0.04 | 0.044 | 0.036 |

Table 3: Sugar percentage (%) at various growth stages of sweet sorghum by different fertilizer doses.

| SUGAR PERCENTAGE | TREATMENT | 40 DAS | 70 DAS | 100 DAS | 130DAS |
|------------------|-----------|--------|--------|---------|---------|
| **NITROGEN** | | | | | |
| N$_1$ | 5.34 | 7.32 | 7.52 | 7.36 |
| N$_2$ | 6.83 | 8.82 | 9.05 | 8.89 |
| N$_3$ | 7.62 | 9.62 | 9.84 | 9.68 |
| SE | 0.0081 | 0.0095 | 0.0207 | 0.0229 |
| LSD | 0.0164 | 0.0154 | 0.0422 | 0.0466 |
| **POTASSIUM** | | | | | |
| K$_1$ | 6.46 | 8.45 | 8.66 | 8.49 |
| K$_2$ | 6.62 | 8.61 | 8.82 | 8.65 |
| K$_3$ | 6.71 | 8.7 | 8.93 | 8.79 |
| SE | 0.0081 | 0.0095 | 0.0207 | 0.0229 |
| LSD | 0.0164 | 0.0154 | 0.0422 | 0.0466 |
| **PHOSPHORUS** | | | | | |
| P$_1$ | 6.4 | 8.38 | 8.58 | 8.42 |
| P$_2$ | 6.79 | 8.79 | 9.03 | 8.87 |
| SE | 0.0066 | 0.0078 | 0.0169 | 0.0187 |
| LSD | 0.0134 | 0.0158 | 0.0344 | 0.038 |

from each other (Table 2). In case of nitrogen, N$_1$ (100 kg/ha) gave the highest green biomass data (26.68 t/ha) at 100 DAS. This result pointed out that increasing nitrogen application helps sweet sorghum in increasing production. This was as similar to the results of Mengel and Kirkby (2001). In the case of potassium, K$_1$ (100 kg/ha) gave highest green biomass data (26.39 t/ha) at 100DAS, which was similarly observed by Sharma and Kumari (1996) about the increase in K fertilizer application. On the other hand in the case of phosphorus dose P$_1$ (60 kg/ha) on sweet sorghum did not show any drastic change in green biomass. However, the highest green biomass (t/ha) yield was found on 100 DAS (26.84 t/ha) at N$_1$P$_3$K$_1$ treatment combination. Green biomass shows an independent result from the dose that is effective for plant height.
found that applying potassium 90 kg/ha gave the highest sugar percentage (8.9%), thereby indicating that increasing potassium application is not much significantly helpful to improve sweet sorghum crop sugar percentage. On the other hand phosphorus $P_3$ (60 kg/ha) of sweet sorghum showed highest sugar percentage (9.03%). In case of Interaction effects between nitrogen, potassium and phosphorus, the treatment combination $N_PK_3$ gave the highest sugar percentage (10.07%) that was found at 100 DAS. The sugar percentage got decreased in 130 DAS.

**Effect on sugar yield (kg/ha):** The results showed that the effect of sugar yield (kg/ha) with individual doses of nitrogen, potassium and phosphorus were significantly different from each other (Table 4). In case of nitrogen, the level $N_3$ (100 kg/ha) gave the highest sugar yield (1842.06 kg/ha) at 100 DAS. In case of potassium, $K_3$ (100 kg/ha) gave the highest sugar yield (1656.01 kg/ha) at 100 DAS and phosphorus fertilizer dose $P_3$ (60 kg/ha) showed high sugar yield (1673.94 kg/ha) on 100 DAS. In case of Interaction effects between nitrogen, potassium and phosphorus the treatment $N_PK_3$ recorded, the highest sugar yield (1896.88 kg/ha) which was found in 100 DAS treatment combination. Although $N_PK_3$ combination shows the highest result, if the LSD value is subtracted from the value and the resultant includes a broad range, which indicates that lower doses also equally have the same impact and should be cost-effective rather than the particular higher dose of fertilizer application.

**CONCLUSION**

Nitrogen is undoubtedly a basic and necessity fertilizer nutrient for sorghum cropping system. Any major essential factor cannot be replaced by any other as each of these influences specific activities (hormonal regulation, growth promoting pathways, nutrient uptake, and photosynthetic pathways, energy production and utilisation transport chains and so on). In contrary, excessive use of any fertilizer even nitrogen, the most important one, can be hazardous resulting soil pH deterioration and affect cost issues as well. Keeping all these in mind, the low doses of nitrogen were applied and it is clearly observed that the moderate to high doses of phosphorus and potassium can balance the situation. Growth of the plant as well as sugar yield showed healthy outputs. But after a certain time like in latest days, the rate of increase of brix concentration is somewhat affected and reached the threshold in before time in comparison to the higher Nitrogen dose conditions. Therefore, the inference states that the higher dose of nitrogen (100 kg per ha) medium dose of phosphorus (50 kg per ha) and higher dose of potassium (100 kg per ha) can give a basic support to the sorghum cropping system to a certain limit when the rest of the environment is favourable. This treatment recorded higher biomass, sugar percentage and net return in sweet sorghum.

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**Table 4:** Sugar yield (kg/ha) at various growth stages of sweet sorghum by different fertilizer doses.

| TREATMENT | 40 DAS | 70 DAS | 100 DAS | 130DAS |
|-----------|--------|--------|---------|--------|
| **NITROGEN** |        |        |         |        |
| $N_1$     | 561.17 | 1000.66| 1367.22 | 1277.29|
| $N_2$     | 732.32 | 1222.17| 1672.84 | 1565.5 |
| $N_3$     | 837.81 | 1357.4 | 1842.06 | 1735.09|
| SE        | 0.6    | 1.5    | 3.89    | 3.89   |
| LSD       | 1.22   | 3.055  | 7.9     | 7.9    |
| **POTASSIUM** |       |        |         |        |
| $K_1$     | 689.91 | 1169.27| 1594.89 | 1491.33|
| $K_2$     | 713.63 | 1196.83| 1631.23 | 1526.6 |
| $K_3$     | 727.75 | 1214.12| 1656.01 | 1559.95|
| SE        | 0.6    | 1.5    | 3.89    | 3.89   |
| LSD       | 1.22   | 3.055  | 7.9     | 7.9    |
| **PHOSPHORUS** |      |        |         |        |
| $P_1$     | 685.94 | 1158.56| 1580.81 | 1474.15|
| $P_2$     | 734.93 | 1228.25| 1673.94 | 1577.77|
| $P_3$     | 749.19 | 1237.24| 1662.75 | 1545.68|
| SE        | 0.49   | 1.23   | 3.17    | 3.18   |
| LSD       | 0.99   | 2.49   | 6.45    | 6.46   |
| **INTERACTION** |    |        |         |        |
| $N_PK_1$  | 517.51 | 944.05 | 1289.9  | 1188.68|
| $N_PK_2$  | 528.13 | 953    | 1301.52 | 1202.39|
| $N_PK_3$  | 532.11 | 959.01 | 1309.02 | 1231.89|
| $N_PK_4$  | 695.01 | 1169.55| 1598.79 | 1485.26|
| $N_PK_5$  | 715.81 | 1197.25| 1636.84 | 1518.73|
| $N_PK_6$  | 731.93 | 1217.24| 1662.75 | 1545.68|
| $N_PK_7$  | 786.13 | 1288.33| 1756.69 | 1638.92|
| $N_PK_8$  | 822.54 | 1337.5 | 1821.78 | 1701.02|
| $N_PK_9$  | 844.25 | 1361.14| 1850    | 1754.78|
| $N_PK_10$ | 579.86 | 1027.99| 1409.16 | 1324.23|
| $N_PK_11$ | 600.84 | 1051.9 | 1439.47 | 1350.58|
| $N_PK_12$ | 608.57 | 1067.99| 1454.27 | 1365.95|
| $N_PK_13$ | 729.92 | 1225.16| 1670.71 | 1573.69|
| $N_PK_14$ | 748.83 | 1248.18| 1704.82 | 1602.57|
| $N_PK_15$ | 772.4  | 1275.63| 1673.15 | 1665.08|
| $N_PK_16$ | 831.04 | 1360.55| 1844.12 | 1735.18|
| $N_PK_17$ | 865.64 | 1393.15| 1882.92 | 1784.29|
| $N_PK_18$ | 877.24 | 1403.7 | 1896.88 | 1796.34|
| SE        | 1.47   | 3.68   | 9.52    | 9.53   |
| LSD       | 2.98   | 7.48   | 19.35   | 19.37  |

Effect on sugar percentage (%): The results showed that the effect of sugar percentage (%) on individual doses of nitrogen, potassium, and phosphorus were significantly different from each other (Table 3). In case of nitrogen, $N_1$ (100 kg/ha) gave high sugar percentage (9.84%) at 130 DAS but Barik and Roy (2015)
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