

## Effect of improved nutrient management on quality and nutrient uptake of castor (*Ricinus communis*)

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### ABSTRACT

A field experiment was conducted at the Agronomy Instructional Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Gujarat, during the *kharif* seasons of 2020–21 and 2021–22 to evaluate the “Impact of Green Manure and Nutrient Management on Quality and Nutrient Uptake in Castor (*Ricinus communis* L.)”. The experiment involved 20 treatment combinations, consisting of four green manure treatments (Control, Sunhemp, Clusterbean, and Cowpea) and five nutrient management treatments (100% Recommended Dose of Fertilizer (RDF), 75% RDF + 1% Banana pseudostem sap foliar spray at 30, 60, and 90 DAS, 75% RDF + 1.5% Banana pseudostem sap foliar spray at 30, 60, and 90 DAS, 100% RDF + 1% Banana pseudostem sap foliar spray at 30, 60, and 90 DAS, and 100% RDF + 1.5% Banana pseudostem sap foliar spray at 30, 60, and 90 DAS). A split-plot design with three replications was used. Results showed that the sunhemp green manure treatment significantly increased oil yield upto 1665 kg/ha and nutrient (N, P, K) uptake by the castor stalk. The application of 100% RDF combined with a 1.5% Banana pseudostem sap foliar spray at 30, 60, and 90 DAS led to significantly higher nutrient uptake by both seed and stalk compared to other treatments. However, the combined application of green manuring and nutrient management did not significantly affect nutrient uptake by seed and stalk. Although nutrient management treatments did not affect oil content in castor seed, the highest oil yield and nutrient uptake were observed with 100% RDF + 1.5% Banana pseudostem sap foliar spray at 30, 60, and 90 DAS, followed by the 1% sap foliar spray treatment. Overall, growing sunhemp as green manure at 45 DAS, followed by 75% RDF application and 1.5% Banana pseudostem sap foliar spray at 30, 60, and 90 DAS, improved oil yield and nutrient uptake in castor.

**Key words:** Green manure, Nutrient management, Oil yield, Quality nutrient uptake

Castor is an industrially important non-edible oilseed crop widely cultivated in the arid and semi-arid regions of the world. India, Brazil and China are the most important castor-growing countries in the world. At present, India is the world leader in castor production. The area during the year 2021–22 was 8.11 lakh ha with the production of 17.95 lakh tonnes and productivity of 2,228 kg/ha (Anonymous, 2022). In Gujarat, the area under castor during the year 2021–22 was 6.52 lakh ha with the production of 15.47 lakh tonnes and productivity of 2,371 kg/ha (Anonymous, 2022). In Gujarat, castor is mainly grown in the Banaskantha, Mehsana, Patan and Sabarkantha districts of

North Gujarat.

The use of chemical fertilizers alone may not keep pace with time in maintaining soil health for sustaining productivity. Growing concern about the sustainability of oilseed-based cropping systems coupled with rising costs of chemical fertilizers has renewed interest in the use of organic manures along with green manuring. The economic significance of organic manures has gained momentum in recent years, because of their utilization as a renewable source of energy, their effects on maintaining soil fertility, increasing nutrient use efficiency, improving soil physical conditions and their role in getting a sustainable yield of crops. The integrated approach of nutrient supply by inorganic and organic fertilizers is gaining importance because this system not only reduces the use of costly inorganic fertilizers but is also an environment friendly approach. Besides these, it also involves green manuring and off-farm waste recycling with the overall objective of sustainable production, maintaining resources and environmental quality (FAO, 1988).

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Green manuring is a practice of ploughing or turning into the soil un-decomposed fresh green plant tissue to improve the fertility status and physical structure of the soil. Unlike synthetic N fertilizer, legumes utilized as green manures represent a potentially renewable source of on-farm biologically fixed N and may also fix and add a large amount of carbon to cropping systems. The plant material is mostly of leguminous plants like sunhemp (*Crotalaria juncea*), dhaincha (*Sesbania aculeate*, *Sesbania rostrata*), cowpea (*Vigna unguiculata*) and cluster bean (*Cymposis tetragonoloba*) etc. Banana is the most important fruit crop widely cultivated in India mainly for fruit purposes. But after the fruit harvest, a huge quantity of pseudostems are generated as waste. Pseudostem sap contains essential macro and micronutrients, growth-promoting substances like cytokinin and GA<sub>3</sub> (Gibberellic Acid) and it can use as an organic nutritive supplier to the crops to increase their crop growth and yield. This nutritive enriched sap can be applied to the plants as the foliar spray to enhance the plant growth and yield, and it is one of the most cost-effective fertilizers can found naturally.

### MATERIALS AND METHODS

The field experiment was laid out in Plot No. B-6 during *kharif* season of the years 2020–21 and 2021–22 at Agronomy Instructional Farm, Department of Agronomy, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat to study the effect of green manure and nutrient management on Castor nutrient content, uptake and soil fertility. The climate of this region is sub-tropical monsoon type and falls under the semi-arid region. The total rainfall received during the crop growth period of the first year (2020–21) was 1180.5 mm with rainy days of 37 and in the second year (2021–22) was 487 mm with rainy days of 27. The average rainfall of Sardarkrushinagar is 712.7 mm. The weekly mean evaporation ranged from 2.7 to 7.6 mm with an average of 5.3 mm during the year 2020-21 and 3.3 to 7.9 mm with an average of 5.7 mm during the year 2021-22. This showed that the average evaporation did not vary during both the years 2020-21 and 2021-22 of experimentation. To assess the physico-chemical properties of the soil of the experimental field, the soil samples were taken randomly from different spots of the experimental field to a depth of 0-15 before layout considering all possible precautions for soil sampling. The soil of the experimental plot was loamy sand in texture having pH 7.58 and EC 0.16 dS/m at 0-15 cm soil depth during 2020-21. Analysis showed that the experimental soil was low in organic carbon (0.34%) and available nitrogen (162.8 kg/ha), medium in phosphorus (39.2 kg/ha) and high in potassium (254.3) status. The castor, sunhemp, cluster bean and

cowpea variety are GCH 8, Local, GG 2 and GC 4 respectively.

Twenty treatment combination of green manuring and nutrient management viz., Control (No green manuring) + 100% RDF (G<sub>0</sub>N<sub>1</sub>), Control (No green manuring) + 75% RDF + Banana pseudostem sap @1% as foliar spray at 30, 60 and 90 DAS (G<sub>0</sub>N<sub>2</sub>), Control (No green manuring) + 75% RDF + Banana pseudostem sap @1.5% (G<sub>0</sub>N<sub>3</sub>), Control (No green manuring) + 100% RDF + Banana pseudostem sap @1% (G<sub>0</sub>N<sub>4</sub>), Control (No green manuring) + 100% RDF + Banana pseudostem sap @1.5% (G<sub>0</sub>N<sub>5</sub>), Sunhemp + 100% RDF (G<sub>1</sub>N<sub>1</sub>), Sunhemp + 75% RDF + Banana pseudostem sap @1% (G<sub>1</sub>N<sub>2</sub>), Sunhemp + 75% RDF + Banana pseudostem sap @1.5% (G<sub>1</sub>N<sub>3</sub>), Sunhemp + 100% RDF + Banana pseudostem sap @1% (G<sub>1</sub>N<sub>4</sub>), Sunhemp + 100% RDF + Banana pseudostem sap @1.5% (G<sub>1</sub>N<sub>5</sub>), Cluster bean + 100% RDF (G<sub>2</sub>N<sub>1</sub>), Cluster bean + 75% RDF + Banana pseudostem sap @1% (G<sub>2</sub>N<sub>2</sub>), Cluster bean + 75% RDF + Banana pseudostem sap @1.5% (G<sub>2</sub>N<sub>3</sub>), Cluster bean + 100% RDF + Banana pseudostem sap @1% (G<sub>2</sub>N<sub>4</sub>), Cluster bean + 100% RDF + Banana pseudostem sap @1.5% (G<sub>2</sub>N<sub>5</sub>), Cowpea + 100% RDF (G<sub>3</sub>N<sub>1</sub>), Cowpea + 75% RDF + Banana pseudostem sap @1% (G<sub>3</sub>N<sub>2</sub>), Cowpea + 75% RDF + Banana pseudostem sap @1.5% (G<sub>3</sub>N<sub>3</sub>), Cowpea + 100% RDF + Banana pseudostem sap @1% (G<sub>3</sub>N<sub>4</sub>), Cowpea + 100% RDF + Banana pseudostem sap @1.5% (G<sub>3</sub>N<sub>5</sub>) were tested in split-plot design with three replications. In *kharif*, the experimental field was prepared by harrowing and planking. The required quantity of green manure seeds of sunhemp, cluster bean and cowpea were sown by broadcasting and shallow tillage was carried out by the cultivator to mix the seeds with soil followed by planking. The first irrigation was given immediately after sowing to ensure the germination of seed through check basin method. Sufficient and timely rainfall was received during both years for better growth of green manure crops. Green manure crops incorporated into the soil as in-situ in each plot at 49 and 45 days after sowing during 2020-21 and 2021-22, respectively at the flowering stage with the help of a disc harrow for its decomposition.

The experimental field was prepared for the planting of castor by cross cultivation with a tractor-drawn cultivator after the complete decomposition of green manure crops. Harrowing was also done for obtain a good tilth. Thereafter, the experiment was laid out in a split-plot design as per the layout plan. The furrows were opened manually about 6-7 cm deep at the time of sowing in each plot.

Among the total nitrogen, one-third of the recommended dose of nitrogen was applied in the form of urea and the entire dose of phosphorus through DAP was applied as a basal dose at the time of sowing. After fertilizer

**Table 1.** Chemical composition of banana pseudostem sap

| pH  | Content of nutrients |               |               |                |                |                |                |
|-----|----------------------|---------------|---------------|----------------|----------------|----------------|----------------|
|     | Total N (%)          | Total P (ppm) | Total K (ppm) | Total Fe (ppm) | Total Mn (ppm) | Total Zn (ppm) | Total Cu (ppm) |
| 4.5 | 0.857                | 175           | 1150          | 86.09          | 6.73           | 4.61           | 0.97           |

Note: Banana pseudostem sap @ 1% and 1.5% foliar spray at 30, 60 and 90 DAS

application, the furrows were covered with soil in such a way that the furrows remained partly opened for dibbling of seed. The remaining dose of nitrogen was top-dressed in three equal splits from urea according to soil moisture availability.

Seeds of castor hybrid GCH-8 were dibbled two seeds at each hill manually in opened furrows at the depth of 4.0-5.0 cm. The crop was sown by keeping 150 cm inter and 120 cm intra-row spacing. For maintaining the plant population, gap filling was carried out at around 15 DAS. Thinning was done by maintaining one healthy plant at each hill by cutting additional seedlings at 30 DAS during 2020-21 and 2021-22. As per the need of crop, two interculturing by bullock drawn hoe and two hand weeding operations were carried out to keep the crop free from weeds. Interculturing was done to remove weeds, pulverizing the soil for better aeration and conserve moisture in the soil. Two-hand weeding operations were carried out in castor crops to minimize the early crop weed competition during the crop season.

Representative samples were taken from each net plot after the harvest of the crop for the estimation of N, P and K content. N, P, K was determination by Micro Kjeldahl's method (Jackson, 1974), Vanadomolybdo phosphoric acid yellow color method (Jackson, 1974) and Flame Photometer method (Jackson, 1974) respectively. The soil samples were drawn from 0-15 cm depth before experimentation (initial) at first year and after harvest of the crop during both the years were oven-dried at 105°C, and then sieved through a 2 mm size sieve. The initial composite soil sample was analysed for different physico-chemical properties like EC, pH, organic carbon, N, P, and K. The soil samples collected after the harvest of castor crops in both the years were used for the determination of EC, pH, organic carbon, available N, available P<sub>2</sub>O<sub>5</sub> and available K<sub>2</sub>O by following Potentiometry (1:2.5), Conductometry (1: 2 soil:water), Walkley and Black's method (Walkley & Black, 1934), Alkaline Potassium Permanganate method (Subbiah and Asija, 1956), 0.5 M sodium bicarbonate (1:20) and determined calorimetrically (Olsen *et al.* 1954) and neutral ammonium acetate (1:5) and determined by the flame photometer method (Jackson, 1974) respectively.

### *Banana pseudostem sap*

Foliar application of enriched banana pseudostem sap @1% and 1.5% was done at 30, 60 and 90 DAS as per the treatments. This product is patented as a brand name of Nauroji, by Navsari Agricultural University, Navsari, Gujarat.

The statistical analysis was carried out as described by Panse and Sukhatme (1985). The values of calculated "F" were worked out and compared with the value of table "F" at 5 % level of significance. The pooled analysis of the 2 years data was carried out as per procedure suggested by Panse and Sukhatme (1985).

## RESULTS AND DISCUSSION

The oil content (%) (Table 2) in castor seed was non-significant with different green manuring treatments during both the years and on pooled mean. The synthesis of oil in the seed is a function of genetic makeup of hybrid so not much altered. These results are in conformity with the results reported by Chauhan (2016) and Bassegio *et al.* (2016). A perusal of data presented in Table 2 revealed that oil content in castor seed did not affect significantly due to different treatments of nutrient management during both the years and in pooled results. These results are in conformity with the results reported by Lakshmi and Reddy (2006) and Shridharamurthy *et al.* (2008) and Interaction effect of green manuring and nutrient management treatments in respect to oil content (%) was found non-significant during 20-21, 21-22 and in pooled data.

Data (Table 3) showed that the oil yield of castor significantly affected due to different green manuring treatments during both the years and in pooled results. Significantly the highest oil yield of 1692 kg/ha in first year and 1665 kg/ha in pooled basis were recorded with incorporation of sunhemp as green manure crop. While during second year green manuring of sunhemp was found at par with cowpea. significantly lower oil yield by castor seed (1311 kg/ha in 20-21, 1217 kg/ha in 21-22 and 1264 kg/ha in pooled data was recorded with control (No green manuring).

The beneficial effect of incorporation of sunhemp as green manure crop on seed yield of castor was observed in present study could be attributed to the fact that green biomass of sunhemp supply of almost all the essential plant

nutrients and also increasing the availability of native soil nutrients due to increased microbial activity. The increase in seed yield directly resulted in higher oil yield. These results are in line with the findings of Chauhan (2016).

Data presented in Table 3 showed that the oil yield of castor was influenced significantly due to nutrient management treatments during both the years and in pooled results. Results indicated that application of 100% RDF + banana pseudostem sap @1.5% as foliar spray at 30, 60 and 90 DAS recorded significantly higher oil yield of 1561 kg/ha in 20-21, 1483 kg/ha in 21-22 and 1522 kg/ha in pooled basis, and remained at par with 100% RDF + banana pseudostem sap @1% as foliar spray at 30, 60 and 90 DAS (1534 kg/ha in first year, 1472 kg/ha in second year and 1503 kg/ha in pooled basis and with 75% RDF + banana pseudostem sap @1.5% as foliar spray at 30, 60 and 90 DAS (1471 kg/ha in first year and 1417 kg/ha in second year.

Significantly lower oil yield (1405 kg/ha in 20-21, 1330 kg/ha in 2021-22 and 1367 kg/ha in pooled basis) was obtained by application of 100% RDF alone.

This might be due to better nutrient status in the soil and better assimilation of nutrients by plants which was reflected in the reproductive health and quality of seed. Sig-

nificantly higher castor seed yield and marginally higher value of oil content (Table 2) observed under above mentioned treatments. These results are in accordance with the findings of Patel *et al.* (2010), Bijarnia *et al.* (2013), Reddy *et al.* (2013) and Saini *et al.* (2022) recorded significantly higher value of oil yield.

The interaction effect of green manuring and nutrient management treatments did not reach to level of significance with respect to oil yield (kg/ha) during both the years as well as in pooled results.

### Effect of green manuring and nutrient management on plant nutrient uptake

#### N uptake by seed and stalk of castor

The data pertaining to N uptake (kg/ha) by seed and stalk of castor were influenced significantly with various green manuring treatments during both the years as well as in pooled analysis. Incorporation of sunhemp as a green manuring recorded significantly the highest N uptake by seed 114.13 kg/ha in first year, 112.59 kg/ha in second year and 113.36 kg/ha in pooled basis and stalk (63.30 kg/ha in first year, 60.77 kg/ha in second year and 62.03 kg/ha in pooled basis.

The lower N uptake by seed was observed in control

**Table 2.** Effect of green manuring and nutrient management practices on oil content of castor

| Treatment   | Oil content (%) |         |        |
|---|-----------------|---------|--------|
|   | 2020–21         | 2021–22 | Pooled |
| [A] Main plot: Green manuring (G):  |                 |         |        |
| G <sub>0</sub> , Control (No green manuring)  | 48.24           | 47.48   | 47.86  |
| G <sub>1</sub> , Sunhemp  | 49.26           | 49.61   | 49.43  |
| G <sub>2</sub> , Cluster bean   | 49.01           | 48.65   | 48.83  |
| G <sub>3</sub> , Cowpea   | 48.62           | 49.12   | 48.87  |
| SEm±  | 0.51            | 0.63    | 0.40   |
| CD (P=0.05)   | NS              | NS      | NS     |
| CV %  | 4.01            | 4.98    | 4.52   |
| [B] Sub-plot: Nutrient management (N):  |                 |         |        |
| N <sub>1</sub> , 100% RDF   | 48.13           | 48.05   | 48.09  |
| N <sub>2</sub> , 75% RDF + Banana pseudostem sap @ 1% as foliar spray at 30, 60 and 90 DAS    | 48.30           | 48.46   | 48.38  |
| N <sub>3</sub> , 75% RDF + Banana pseudostem sap @ 1.5% as foliar spray at 30, 60 and 90 DAS  | 48.96           | 48.61   | 48.78  |
| N <sub>4</sub> , 100% RDF + Banana pseudostem sap @ 1% as foliar spray at 30, 60 and 90 DAS   | 49.19           | 49.27   | 49.23  |
| N <sub>5</sub> , 100% RDF + Banana pseudostem sap @ 1.5% as foliar spray at 30, 60 and 90 DAS | 49.33           | 49.19   | 49.26  |
| SEm±  | 0.40            | 0.62    | 0.37   |
| CD (P=0.05)   | NS              | NS      | NS     |
| Interaction:  |                 |         |        |
| G × N   | NS              | NS      | NS     |
| Y × G   | -               | -       | NS     |
| Y × N   | -               | -       | NS     |
| Y × G × N   | -               | -       | NS     |
| CV %  | 2.82            | 4.38    | 3.69   |

**Table 3.** Effect of green manuring and nutrient management practices on oil yield of castor

| Treatment   | Oil yield (kg/ha) |         |        |
|---|-------------------|---------|--------|
|   | 2020–21           | 2021–22 | Pooled |
| [A] Main plot: Green manuring (G):  |                   |         |        |
| G <sub>0</sub> , Control (No green manuring)  | 1,311             | 1,217   | 1,264  |
| G <sub>1</sub> , Sunhemp  | 1,692             | 1,638   | 1,665  |
| G <sub>2</sub> , Cluster bean   | 1,426             | 1,354   | 1,390  |
| G <sub>3</sub> , Cowpea   | 1,489             | 1,441   | 1,465  |
| SEM±  | 44.26             | 56.85   | 36.02  |
| CD (P=0.05)   | 153               | 197     | 111    |
| CV %  | 11.58             | 15.59   | 13.65  |
| [B] Sub-plot: Nutrient management (N):  |                   |         |        |
| N <sub>1</sub> , 100% RDF   | 1,405             | 1,330   | 1,367  |
| N <sub>2</sub> , 75% RDF + Banana pseudostem sap @ 1% as foliar spray at 30, 60 and 90 DAS    | 1,428             | 1,360   | 1,394  |
| N <sub>3</sub> , 75% RDF + Banana pseudostem sap @ 1.5% as foliar spray at 30, 60 and 90 DAS  | 1,471             | 1,417   | 1,444  |
| N <sub>4</sub> , 100% RDF + Banana pseudostem sap @ 1% as foliar spray at 30, 60 and 90 DAS   | 1,534             | 1,472   | 1,503  |
| N <sub>5</sub> , 100% RDF + Banana pseudostem sap @ 1.5% as foliar spray at 30, 60 and 90 DAS | 1,561             | 1,483   | 1,522  |
| SEM±  | 35.60             | 39.13   | 26.45  |
| CD (P=0.05)   | 103               | 113     | 75     |
| Interaction:  |                   |         |        |
| G × N   | NS                | NS      | NS     |
| Y × G   | -                 | -       | NS     |
| Y × N   | -                 | -       | NS     |
| Y × G × N   | -                 | -       | NS     |
| CV %  | 8.33              | 9.60    | 8.96   |

(No green manuring) with values of 84.11 kg/ha in first year, 77.50 kg/ha in second year and 80.81 kg/ha in pooled basis and 45.95 kg/ha in first year, 43.87 kg/ha in second year and 44.91 kg/ha in pooled basis by stalk.

The higher N uptake by incorporation of sunhemp as green manure crop may be due to higher seed (3367 kg/ha) and stalk yield (5580 kg/ha) of castor as well as higher nitrogen content in seed and stalk (Table 4 and 5). These results are in conformity with the findings of More *et al.* (2005) and Joshi (2021).

The data indicated that application of different nutrient management treatments significantly influenced the N uptake by seed and stalk of castor in individual year and in pooled data.

Significantly higher uptake of N by seed (103.91, 99.51 and 101.71 kg/ha) and stalk (58.10, 55.54 and 56.82 kg/ha) of stalk was recorded with 100% RDF + banana pseudostem sap @1.5% at 30, 60 and 90 DAS (N<sub>5</sub>) but it remained at par with 100% RDF + banana pseudostem sap @1% at 30, 60 and 90 DAS (101.30, 96.47 and 98.88 kg/ha) by seed and (56.58, 53.81 and 55.19 kg/ha) by stalk during 2020-21, 2021-22 and in pooled results. Application of 75% RDF + banana pseudostem sap @1.5% at 30, 60 and 90 DAS (92.77 kg/ha) was also remained at par with

N<sub>5</sub> (100% RDF + 1.5% Banana pseudostem sap foliar spray at 30, 60, and 90 DAS) in N uptake by seed during second year and by stalk (54.64 kg/ha) of castor during first year.

Significantly lower N uptakes by seed 92.88 kg/ha in 20-21, 88.60 kg/ha in 21-22 and 90.74 kg/ha in pooled basis, and by stalk (49.35 kg/ha in 20-21, 46.57 kg/ha in 21-22 and 47.96 kg/ha in pooled basis) were obtained under application of 100% RDF alone.

Higher N uptake by seed and stalk of castor with RDF either 100% or 75% with banana pseudostem sap might be due to increased supply of nutrients directly through organic and inorganic sources to the crop as well as indirectly through reducing the loss of nutrients from soil solution resulting in to better growth, higher seed and stalk yield as well as more nutrient concentration. Application of banana pseudostem sap as an organic source increased the growth of the plant thus facilitated higher uptake of N by castor seed and stalk. These results are corroborate with those reported by Patil (2016), Gudadhe *et al.* (2017) and Joshi (2021).

Results presented in Table 6 and 7 indicated that interaction between non-significant due to different treatments of green manuring and nutrient management was found

**Table 4.** Effect of green manuring and nutrient management practices on N, P and K content in seed of castor

| Treatments                             | N (%)   |         |        | P (%)   |         |        | K (%)   |         |        |
|--|---------|---------|--------|---------|---------|--------|---------|---------|--------|
|  | 2020-21 | 2021-22 | Pooled | 2020-21 | 2021-22 | Pooled | 2020-21 | 2021-22 | Pooled |
|  |         |         |        |         |         |        |         |         |        |
| [A] Main plot : Green manuring (G):    |         |         |        |         |         |        |         |         |        |
| G <sub>0</sub>                         | 3.097   | 3.029   | 3.063  | 0.948   | 0.916   | 0.932  | 1.047   | 1.066   | 1.057  |
| G <sub>1</sub>                         | 3.322   | 3.411   | 3.366  | 1.013   | 0.990   | 1.002  | 1.107   | 1.099   | 1.103  |
| G <sub>2</sub>                         | 3.188   | 3.149   | 3.168  | 0.936   | 0.965   | 0.950  | 1.104   | 1.072   | 1.088  |
| G <sub>3</sub>                         | 3.231   | 3.251   | 3.241  | 0.973   | 0.992   | 0.982  | 1.103   | 1.098   | 1.101  |
| SEm±                                   | 0.036   | 0.050   | 0.031  | 0.012   | 0.014   | 0.009  | 0.017   | 0.019   | 0.013  |
| CD (P=0.05)                            | 0.123   | 0.173   | 0.094  | 0.04    | 0.05    | 0.03   | NS      | NS      | NS     |
| CV %                                   | 4.30    | 6.02    | 5.23   | 4.64    | 5.55    | 5.12   | 6.00    | 6.86    | 6.44   |
| [B] Sub-plot: Nutrient management (N): |         |         |        |         |         |        |         |         |        |
| N <sub>1</sub>                         | 3.182   | 3.194   | 3.188  | 0.942   | 0.938   | 0.940  | 1.059   | 1.051   | 1.055  |
| N <sub>2</sub>                         | 3.143   | 3.165   | 3.154  | 0.958   | 0.956   | 0.957  | 1.099   | 1.082   | 1.091  |
| N <sub>3</sub>                         | 3.197   | 3.174   | 3.185  | 0.964   | 0.964   | 0.964  | 1.108   | 1.087   | 1.097  |
| N <sub>4</sub>                         | 3.248   | 3.225   | 3.236  | 0.976   | 0.975   | 0.975  | 1.091   | 1.093   | 1.092  |
| N <sub>5</sub>                         | 3.277   | 3.292   | 3.284  | 0.998   | 0.996   | 0.997  | 1.095   | 1.105   | 1.100  |
| S.Em.±                                 | 0.033   | 0.029   | 0.022  | 0.012   | 0.012   | 0.008  | 0.016   | 0.018   | 0.012  |
| C.D.(P=0.05)                           | 0.094   | 0.084   | 0.062  | 0.03    | 0.03    | 0.02   | NS      | NS      | NS     |
| Interaction:                           |         |         |        |         |         |        |         |         |        |
| G × N                                  | NS      | NS      | NS     | NS      | NS      | NS     | NS      | NS      | NS     |
| Y × G                                  | -       | -       | NS     | -       | -       | NS     | -       | -       | NS     |
| Y × N                                  | -       | -       | NS     | -       | -       | NS     | -       | -       | NS     |
| Y × G × N                              | -       | -       | NS     | -       | -       | NS     | -       | -       | NS     |
| C.V.%                                  | 3.51    | 3.14    | 3.33   | 4.23    | 4.21    | 4.22   | 5.11    | 5.72    | 5.42   |

non-significant with respect to N uptake by seed and stalk of castor crop during first year, second year and in pooled analysis.

**P uptake by seed and stalk of castor**

Phosphorus uptake by seed and stalk of castor as influenced by various green manuring and nutrient management treatments are summarized in Table 6 (P uptake by seed (kg/ha) and 7 (P uptake by stalk kg/ha).

The data pertaining to P uptake by seed and stalk of castor were influenced significantly due to different green manuring treatments during both the years as well as in pooled analysis. Green manuring carried out by sunhemp reported significantly the highest P uptake by seed of 34.82 kg/ha in 20–21, 32.68 kg/ha in 21–22 and 33.75 kg/ha in pooled basis and stalk 12.47 kg/ha in 20–21, 11.79 kg/ha in 21–22 and 12.13 kg/ha in pooled basis of castor.

The minimum P uptake by seed 25.80 kg/ha in 20–21, 23.47 kg/ha in 21–22 and 23.47 kg/ha in pooled basis and stalk 9.13 kg/ha in 20–21, 8.92 kg/ha in 21–22 and 9.03 kg/ha in pooled basis was recorded with control (No green manuring).

Higher P uptake by seed and stalk of castor with incorporation of sunhemp as green manure crop might be due to higher seed and stalk yield of castor as well as higher P content in seed and stalk. These results are in conformity with the findings of More *et al.* (2005) and Chauhan (2016).

The data indicated that application of different nutrient management treatments significantly influenced P uptake by seed and stalk of castor both in individual year and in pooled data. significantly higher uptake of P by seed (31.70, 30.00 and 30.85 kg/ha) and stalk (11.57,

Table 5. Effect of green manuring and nutrient management practices on N, P and K content in stalk of castor (pooled data of 2 years)

| Treatment  | N (%)   |         |        | P (%)   |         |        | K (%)   |         |        |
|--|---------|---------|--------|---------|---------|--------|---------|---------|--------|
|  | 2020-21 | 2021-22 | Pooled | 2020-21 | 2021-22 | Pooled | 2020-21 | 2021-22 | Pooled |
| [A] Main plot : Green manuring (G):  |         |         |        |         |         |        |         |         |        |
| G <sub>0</sub> Control (No green manuring)   | 0.984   | 0.983   | 0.983  | 0.195   | 0.200   | 0.198  | 0.288   | 0.294   | 0.291  |
| G <sub>1</sub> Sunhemp   | 1.113   | 1.107   | 1.110  | 0.219   | 0.215   | 0.217  | 0.312   | 0.298   | 0.305  |
| G <sub>2</sub> Cluster bean  | 1.044   | 1.031   | 1.037  | 0.210   | 0.202   | 0.206  | 0.301   | 0.297   | 0.299  |
| G <sub>3</sub> Cowpea  | 1.078   | 1.057   | 1.068  | 0.212   | 0.209   | 0.211  | 0.302   | 0.296   | 0.299  |
| SEM±   | 0.019   | 0.023   | 0.015  | 0.004   | 0.003   | 0.002  | 0.006   | 0.005   | 0.004  |
| CD (P=0.05)  | 0.067   | 0.081   | 0.047  | 0.012   | 0.011   | 0.007  | NS      | NS      | NS     |
| CV %   | 7.15    | 8.71    | 7.96   | 6.52    | 5.72    | 6.14   | 7.67    | 6.53    | 7.13   |
| [B] Sub-plot: Nutrient management (N):   |         |         |        |         |         |        |         |         |        |
| N <sub>1</sub> 100% RDF  | 1.012   | 1.007   | 1.010  | 0.195   | 0.199   | 0.197  | 0.291   | 0.291   | 0.291  |
| N <sub>2</sub> 75% RDF + Banana pseudostem sap @1% as foliar spray at 30, 60 and 90 DAS    | 1.029   | 1.031   | 1.030  | 0.207   | 0.203   | 0.205  | 0.301   | 0.298   | 0.299  |
| N <sub>3</sub> 75% RDF + Banana pseudostem sap @1.5% as foliar spray at 30, 60 and 90 DAS  | 1.060   | 1.048   | 1.054  | 0.211   | 0.203   | 0.207  | 0.299   | 0.297   | 0.298  |
| N <sub>4</sub> 100% RDF + Banana pseudostem sap @1% as foliar spray at 30, 60 and 90 DAS   | 1.084   | 1.058   | 1.071  | 0.215   | 0.211   | 0.213  | 0.306   | 0.297   | 0.302  |
| N <sub>5</sub> 100% RDF + Banana pseudostem sap @1.5% as foliar spray at 30, 60 and 90 DAS | 1.088   | 1.077   | 1.083  | 0.217   | 0.215   | 0.216  | 0.306   | 0.298   | 0.302  |
| SEM±   | 0.020   | 0.015   | 0.013  | 0.003   | 0.003   | 0.002  | 0.006   | 0.005   | 0.004  |
| CD (P=0.05)  | 0.059   | 0.044   | 0.036  | 0.009   | 0.009   | 0.006  | NS      | NS      | NS     |
| Interaction:   |         |         |        |         |         |        |         |         |        |
| G × N  | NS      | NS      | NS     | NS      | NS      | NS     | NS      | NS      | NS     |
| Y × G  | -       | -       | NS     | -       | -       | NS     | -       | -       | NS     |
| Y × N  | -       | -       | NS     | -       | -       | NS     | -       | -       | NS     |
| Y × G × N  | -       | -       | NS     | -       | -       | NS     | -       | -       | NS     |
| CV %   | 6.68    | 5.12    | 5.96   | 5.07    | 5.10    | 5.08   | 6.95    | 5.85    | 6.43   |

11.09 and 11.33 kg/ha) was recorded with application of 100% RDF + banana pseudostem sap @1.5% at 30, 60 and 90 DAS but it remained par with 100% RDF + banana pseudostem sap @1% at 30, 60 and 90 DAS (30.51, 29.21 and 29.86 kg/ha) by seed and (11.22, 10.71 and 10.96 kg/ha) by stalk. Application of 75% RDF + banana pseudostem sap @1.5% at 30, 60 and 90 DAS) also remained at par with N<sub>5</sub> (100% RDF + 1.5% Banana pseudostem sap foliar spray at 30, 60, and 90 DAS) in P uptake by seed (28.11 and 28.56 kg/ha) during second year and pooled data.

Significantly lower P uptake by seed 27.53 kg/ha in first year, 26.00 kg/ha in second year and 26.77 kg/ha and stalk 9.54 kg/ha in first year, 9.19 kg/ha in second year and 9.37 kg/ha in pooled basis was obtained under application of 100% RDF alone.

Higher uptake of P by castor seed and stalk with application of either 75% or 100% RDF and banana pseudostem sap @1 or 1.5% might be due to higher P content and yield of seed and stalk in these treatments resulting in higher P uptake by plants. These results are in conformity with those reported by Patil (2016), Gudadhe *et al.* (2017) and Saini *et al.* (2022).

Results revealed that interaction of various green manuring and nutrient management practices was found non-significant with respect to P uptake by seed, and stalk of castor crop during 20-21, 21-22 and in pooled analysis.

#### K uptake by seed and stalk of castor

Potassium uptake by seed and stalk of castor as influenced by various green manure crops and nutrient management treatments are summarized in Table 6 (K up-

**Table 6.** Effect of green manuring and nutrient management practices on N, P and K uptake by seed of castor (pooled data of 2 years)

| Treatment  | N (kg/ha) |         |        | P (kg/ha) |         |        | K (kg/ha) |         |        |
|--|-----------|---------|--------|-----------|---------|--------|-----------|---------|--------|
|  | 2020-21   | 2021-22 | Pooled | 2020-21   | 2021-22 | Pooled | 2020-21   | 2021-22 | Pooled |
| <b>[A] Main plot: Green manuring (G):</b>  |           |         |        |           |         |        |           |         |        |
| G <sub>0</sub> Control (No green manuring)   | 84.11     | 77.50   | 80.81  | 25.80     | 23.47   | 24.64  | 28.43     | 27.28   | 27.86  |
| G <sub>1</sub> Sunhemp   | 114.13    | 112.59  | 113.36 | 34.82     | 32.68   | 33.75  | 37.89     | 36.33   | 37.11  |
| G <sub>2</sub> Cluster bean  | 92.78     | 87.47   | 90.12  | 27.22     | 26.86   | 27.04  | 32.14     | 29.84   | 30.99  |
| G <sub>3</sub> Cowpea  | 98.94     | 95.49   | 97.21  | 29.79     | 29.11   | 29.45  | 33.78     | 32.22   | 33.00  |
| SEm±   | 2.87      | 2.96    | 2.06   | 0.92      | 1.02    | 0.69   | 0.79      | 1.30    | 0.76   |
| CD (P=0.05)  | 9.92      | 10.23   | 6.34   | 3.19      | 3.53    | 2.12   | 2.72      | 4.49    | 2.34   |
| CV %   | 11.39     | 12.28   | 11.82  | 12.14     | 14.08   | 13.10  | 9.20      | 16.01   | 12.89  |
| <b>[B] Sub-plot: Nutrient management (N):</b>  |           |         |        |           |         |        |           |         |        |
| N <sub>1</sub> 100% RDF  | 92.88     | 88.60   | 90.74  | 27.53     | 26.00   | 26.77  | 30.97     | 29.12   | 30.04  |
| N <sub>2</sub> 75% RDF + Banana pseudostem sap @1% as foliar spray at 30, 60 and 90 DAS    | 93.07     | 88.96   | 91.01  | 28.31     | 26.82   | 27.56  | 32.57     | 30.29   | 31.43  |
| N <sub>3</sub> 75% RDF + Banana pseudostem sap @1.5% as foliar spray at 30, 60 and 90 DAS  | 96.30     | 92.77   | 94.53  | 29.00     | 28.11   | 28.56  | 33.34     | 31.64   | 32.49  |
| N <sub>4</sub> 100% RDF + Banana pseudostem sap @1% as foliar spray at 30, 60 and 90 DAS   | 101.30    | 96.47   | 98.88  | 30.51     | 29.21   | 29.86  | 33.87     | 32.67   | 33.27  |
| N <sub>5</sub> 100% RDF + Banana pseudostem sap @1.5% as foliar spray at 30, 60 and 90 DAS | 103.91    | 99.51   | 101.71 | 31.70     | 30.00   | 30.85  | 34.55     | 33.39   | 33.97  |
| S.Em.±   | 2.24      | 2.35    | 1.62   | 0.73      | 0.73    | 0.51   | 0.71      | 1.01    | 0.62   |
| CD (P=0.05)  | 6.46      | 6.76    | 4.58   | 2.09      | 2.09    | 1.45   | 2.04      | 2.90    | 1.74   |
| <b>Interaction:</b>  |           |         |        |           |         |        |           |         |        |
| G × N  | NS        | NS      | NS     | NS        | NS      | NS     | NS        | NS      | NS     |
| Y × G  | -         | -       | NS     | -         | -       | NS     | -         | -       | NS     |
| Y × N  | -         | -       | NS     | -         | -       | NS     | -         | -       | NS     |
| Y × G × N  | -         | -       | NS     | -         | -       | NS     | -         | -       | NS     |
| CV %   | 7.96      | 8.72    | 8.33   | 8.55      | 8.97    | 8.75   | 7.42      | 11.11   | 9.36   |

take by seed (kg/ha) and 7 (K uptake by stalk kg/ha).

The data revealed that incorporation of sunhemp as green manuring recorded significantly higher K uptake by seed 37.89 kg/ha in 20-21, 36.33 kg/ha in 2021-22 and 37.11 kg/ha in pooled basis and stalk of castor 17.75 kg/ha in 20-21, 16.35 kg/ha in 21-22 and 17.05 kg/ha in pooled basis. Which remained statistically at par with green manuring by cowpea crop (32.22 kg/ha) during 21-22.

Significantly lower K uptake by seed 28.43 kg/ha in 20-21, 27.28 kg/ha in 21-22 and 27.86 kg/ha in pooled basis and stalk 13.42 kg/ha in 20-21, 13.14 kg/ha in 21-22 and 13.28 kg/ha in pooled basis of castor was recorded with control. Higher K uptake with incorporation of sunhemp as green manure crop might be due to higher seed and stalk yield as well as higher K content in seed and stalk of castor. These results were in conformity with the findings of More *et al.* (2005) and Joshi (2021).

The data furnished in Table 6 and 7 indicated that application of different nutrient management treatments significantly influenced the K uptake seed and stalk of castor during individual year and in pooled data.

Significantly higher uptake of K by seed (34.55, 33.39 and 33.97 kg/ha) and stalk (16.31, 15.34 and 15.83 kg/ha) of castor was recorded with 100% RDF + banana pseudostem sap @1.5% at 30, 60 and 90 DAS but it remained at par with 100% RDF + banana pseudostem sap @1% at 30, 60 and 90 DAS (33.87, 32.67 and 33.27 kg/ha) by seed and (15.95, 15.09 and 15.52 kg/ha) by stalk and 75% RDF + banana pseudostem sap @1.5% at 30, 60 and 90 DAS K uptake by seed (33.34, 31.64 and 32.49 kg/ha) and

Table 7. Effect of green manuring and nutrient management practices on N, P and K uptake by stalk of castor (pooled data of 2 years)

| Treatment                              | N (kg/ha) |         |        | P (kg/ha) |         |        | K (kg/ha) |         |        |
|--|-----------|---------|--------|-----------|---------|--------|-----------|---------|--------|
|  | 2020-21   | 2021-22 | Pooled | 2020-21   | 2021-22 | Pooled | 2020-21   | 2021-22 | Pooled |
| [A] Main plot: Green manuring (G):     |           |         |        |           |         |        |           |         |        |
| G <sub>0</sub> <sup>1</sup>            | 45.95     | 43.87   | 44.91  | 9.13      | 8.92    | 9.03   | 13.42     | 13.14   | 13.28  |
| G <sub>1</sub> <sup>1</sup>            | 63.30     | 60.77   | 62.03  | 12.47     | 11.79   | 12.13  | 17.75     | 16.35   | 17.05  |
| G <sub>2</sub> <sup>2</sup>            | 51.51     | 48.65   | 50.08  | 10.36     | 9.52    | 9.94   | 14.89     | 14.05   | 14.47  |
| G <sub>3</sub> <sup>3</sup>            | 54.91     | 51.42   | 53.17  | 10.80     | 10.21   | 10.51  | 15.33     | 14.39   | 14.86  |
| SEM±                                   | 1.99      | 1.75    | 1.33   | 0.44      | 0.34    | 0.28   | 0.59      | 0.57    | 0.41   |
| CD (P=0.05)                            | 6.89      | 6.06    | 4.09   | 1.52      | 1.16    | 0.85   | 2.03      | 1.96    | 1.26   |
| CV %                                   | 14.31     | 13.25   | 13.82  | 15.89     | 12.84   | 14.54  | 14.80     | 15.12   | 14.96  |
| [B] Sub-plot: Nutrient management (N): |           |         |        |           |         |        |           |         |        |
| N <sub>1</sub> <sup>1</sup>            | 49.35     | 46.57   | 47.96  | 9.54      | 9.19    | 9.37   | 14.16     | 13.42   | 13.79  |
| N <sub>2</sub> <sup>2</sup>            | 50.91     | 48.30   | 49.60  | 10.25     | 9.53    | 9.89   | 14.89     | 13.95   | 14.42  |
| N <sub>3</sub> <sup>3</sup>            | 54.64     | 51.68   | 53.16  | 10.87     | 10.04   | 10.45  | 15.42     | 14.61   | 15.02  |
| N <sub>4</sub> <sup>4</sup>            | 56.58     | 53.81   | 55.19  | 11.22     | 10.71   | 10.96  | 15.95     | 15.09   | 15.52  |
| N <sub>5</sub> <sup>5</sup>            | 58.10     | 55.54   | 56.82  | 11.57     | 11.09   | 11.33  | 16.31     | 15.34   | 15.83  |
| SEM±                                   | 1.35      | 1.23    | 0.91   | 0.23      | 0.30    | 0.19   | 0.43      | 0.44    | 0.31   |
| CD (P=0.05)                            | 3.89      | 3.55    | 2.58   | 0.67      | 0.86    | 0.53   | 1.25      | 1.26    | 0.87   |
| Interaction:                           |           |         |        |           |         |        |           |         |        |
| G × N                                  | NS        | NS      | NS     | NS        | NS      | NS     | NS        | NS      | NS     |
| Y × G                                  | -         | -       | NS     | -         | -       | NS     | -         | -       | NS     |
| Y × N                                  | -         | -       | NS     | -         | -       | NS     | -         | -       | NS     |
| Y × G × N                              | -         | -       | NS     | -         | -       | NS     | -         | -       | NS     |
| CV %                                   | 8.68      | 8.34    | 8.52   | 7.57      | 10.17   | 8.90   | 9.79      | 10.49   | 10.13  |

by stalk (15.42, 14.61 and 15.02 kg/ha) during 2020-21, 2021-22 and in pooled results, respectively. Application of 75% RDF + banana pseudostem sap @1% at 30, 60 and 90 DAS) also remained statistically at par with respect to K uptake by seed (32.57 kg/ha) during first year.

Significantly lower K uptake by seed 30.97 kg/ha in 20-21, 29.12 kg/ha in 21-22 and 30.04 kg/ha in pooled basis and stalk (14.16 kg/ha in 20-21, 13.42 kg/ha in 21-22 and 13.79 kg/ha in pooled basis) was obtained under application of 100% RDF alone.

Higher K uptake recorded by seed and stalk is associated with higher yield of seed and stalk under treatment either 75% or 100% RDF along with banana pseudostem sap @1% or 1.5% at 30, 60 and 90 DAS. The higher removal of K with this treatment might be due to higher content of K in seed and stalk resulted in higher K uptake. These results are in accordance with those reported by Kumar and Kanjana (2009), Polara *et al.* (2010) and Patil (2016).

Results indicated that interaction between green manuring and nutrient management treatments was found non-significant with respect to K uptake by seed and stalk of castor crop during 2020-21, 2021-22 and in pooled analysis.

#### Seed yield of castor

Data (Table 8) showed that the seed yield of castor significantly affected due to different green manuring treatments during both the years and in pooled results. Significantly the highest oil yield of 3434 kg/ha in first year, 3301 in second year and 3367 kg/ha in pooled basis were recorded with incorporation of sunhemp as green manure crop. Significantly lower seed yield by castor seed (2716 kg/ha in 20-

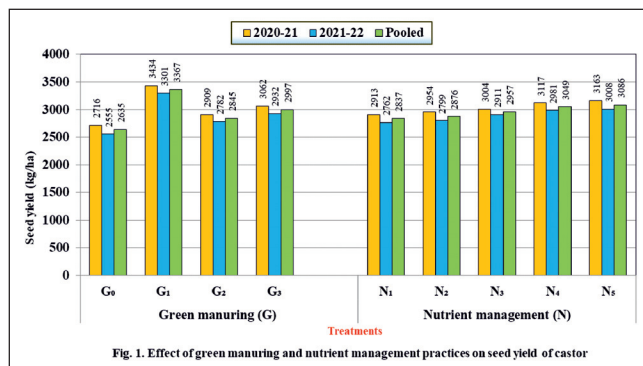


Fig. 1. Effect of green manuring and nutrient management practices on seed yield of castor

21, 2555 kg/ha in 21-22 and 2635 kg/ha in pooled data was recorded with control (No green manuring). Incorporation of sunhemp as a green manure crop recorded 26.4, 29.2 and 27.8 per cent higher seed yield over control during first year, second year and over pooled, respectively.

Seed yield is a complex process and governed by interaction between source (photosynthesis and availability of assimilates) and sink component (storage organs). Thus, as a consequence of marked improvement in both these regulative processes as evidenced from higher accumulation of green biomass and nutrients components under green manure crop of sunhemp led to significant increase in seed

yield. More number of branches and spikes of castor per plant as well as increase number of capsules per spike with sunhemp also responsible for higher total seed yield. The marked variation in yield between green manure crops was observed by Patel *et al.* (2005), Chavan *et al.* (2010) and Joshi (2021).

Data presented in Table 8 showed that the seed yield of castor was influenced significantly due to nutrient management treatments during both the years and in pooled results. Results indicated that application of 100% RDF + banana pseudostem sap @1.5% as foliar spray at 30, 60 and 90 DAS recorded significantly higher seed yield of 3163 kg/ha in 20-21, 3008 kg/ha in 21-22 and 3086 kg/ha in pooled basis, and remained at par with 100% RDF + banana pseudostem sap @1% as foliar spray at 30, 60 and 90 DAS (3117 kg/ha in first year, 2981 kg/ha in second year and 3049 kg/ha in pooled basis and with 75% RDF + banana pseudostem sap @1.5% as foliar spray at 30, 60 and 90 DAS (3004 kg/ha in first year, 2911 kg/ha in second year and 2957 kg/ha in pooled analysis).

Significantly lower seed yield (2913 kg/ha in 20-21, 2762 kg/ha in 2021-22 and 2837 kg/ha in pooled basis was obtained by application of 100% RDF alone.

Table 8. Effect of green manuring and nutrient management practices on seed yield of castor (pooled data of 2 years)

| Treatment  | Seed yield (kg/ha) |         |        |
|--|--------------------|---------|--------|
|  | 2020-21            | 2021-22 | Pooled |
| [A] Main plot : Green manuring (G):  |                    |         |        |
| G <sub>0</sub> , Control (No green manuring)   | 2,716              | 2,555   | 2,635  |
| G <sub>1</sub> , Sunhemp   | 3,434              | 3,301   | 3,367  |
| G <sub>2</sub> , Cluster bean  | 2,909              | 2,782   | 2,845  |
| G <sub>3</sub> , Cowpea  | 3,062              | 2,932   | 2,997  |
| SEm±   | 88.97              | 96.01   | 65.45  |
| CD (P=0.05)  | 308                | 332     | 202    |
| CV %   | 11.37              | 12.86   | 12.11  |
| [B] Sub-plot: Nutrient management (N):   |                    |         |        |
| N <sub>1</sub> , 100% RDF  | 2,913              | 2,762   | 2,837  |
| N <sub>2</sub> , 75% RDF + Banana pseudostem sap @1% as foliar spray at 30, 60 and 90 DAS    | 2,954              | 2,799   | 2,876  |
| N <sub>3</sub> , 75% RDF + Banana pseudostem sap @1.5% as foliar spray at 30, 60 and 90 DAS  | 3,004              | 2,911   | 2,957  |
| N <sub>4</sub> , 100% RDF + Banana pseudostem sap @1% as foliar spray at 30, 60 and 90 DAS   | 3,117              | 2,981   | 3,049  |
| N <sub>5</sub> , 100% RDF + Banana pseudostem sap @1.5% as foliar spray at 30, 60 and 90 DAS | 3,163              | 3,008   | 3,086  |
| SEm±   | 64.53              | 65.68   | 46.04  |
| CD (P=0.05)  | 186                | 189     | 130    |
| Interaction:   |                    |         |        |
| G × N  | NS                 | NS      | NS     |
| Y × G  | -                  | -       | NS     |
| Y × N  | -                  | -       | NS     |
| Y × G × N  | -                  | -       | NS     |
| CV %   | 7.38               | 7.87    | 7.62   |

This could be owing to the nutrients in the banana pseudostem sap such as macronutrients like nitrogen, phosphorus, and potassium, as well as micronutrients that are necessary for plant growth and development. Aside from that, the presence of various amino acids, vitamins, growth regulators such as auxins, gibberellins, and cytokinins, all of which influence yield attributing characters such as length of main spike, number of spikes per plant, and number of capsules per main spike increases the field stand.

The improved plant growth and production features may be due to the simple transport of nutrients and growth stimulants to plants by foliar spray of an optimum dose of banana pseudostem sap. When foliar fed, smaller amounts of growth hormones like gibberellins, cytokinins present in banana pseudostem sap could have created stimuli in the plant system, which increased the production of growth regulator in the cell system, and the action in the plant system stimulated the necessary growth and development of the plant, resulting in a higher yield. Furthermore, the significant increase in yield could be attributed to the continued availability of important plant nutrients (N, P, K, S, Zn, and Fe) throughout various phases of castor growth, as well as improved carbohydrate synthesis and successful photosynthate translocation to the growing sink. Banana pseudostem sap boosted the production of growth-promoting substances, which improved growth and yield attributes, and ultimately seed yield. These results are in agreement with those of Patel *et al.* (2012), Bijarnia *et al.* (2013), Babu *et al.* (2014), Bag *et al.* (2015), Gudadhe *et al.* (2017), Kalariya *et al.* (2018<sup>b</sup>) and Saini *et al.* (2022).

The interaction effect of green manuring and nutrient management treatments did not reach to level of significance with respect to seed yield (kg/ha) during both the years as well as in pooled results.

Thus, it can be concluded that the incorporation of sunhemp at 45 DAS as green manure crop followed by sowing of castor with application of 75% recommended dose of fertilizers (RDF) (90:28:00 N: P<sub>2</sub>O<sub>5</sub>: K<sub>2</sub>O kg/ha) + 1.5% foliar spray of banana pseudostem sap at 30, 60 and 90 days after sowing can be recommended for quality production of castor.

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