*International Journal of Plant & Soil Science*

***33(16): 254-260, 2021; Article no.IJPSS.70634***
***ISSN: 2320-7035***

# Effect of Integrated Nutrient Management on Dry Matter Accumulation and Nutrient Uptake by Maize (Variety-MS 2) under Poplar Agroforestry System

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***Authors' contributions***

*This work was carried out in collaboration among all authors. Author GS designed the study, wrote the first draft of the manuscript. Author AMW managed the literature, draft checking and supervision, Author PKR conceptualization, visualization, managed the analyses of the study. Author ACD Editing, performed analysis. All authors read and approved the final manuscript.*

***Article Information***

DOI: 10.9734/IJPSS/2021/v33i1630543
Editor(s):
(1) Prof. Junhong Bai, Beijing Normal University, China.
(2) Prof. Faruk Toklu, Vocational School of Kozan, University of Çukurova, Turkey.
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(2) Sadek AbdelWahed Salem, National Research Centre, Egypt.
Complete Peer review History: https://www.sdiarticle4.com/review-history/70634

***Original Research Article***

***Received 07 May 2021***
***Accepted 14 July 2021***
***Published 19 July 2021***

## ABSTRACT

**Aims:** To evaluate the influence of farmyard manure, vermicompost, mustard oil cake, poultry manure, and inorganic fertilisers (N, P, K) on maize dry matter buildup and nutrient uptake by plants, as well as to demonstrate how maize may be produced in a poplar agroforestry system.
**Study Design:** Randomized block design.
**Place and Duration of Study**: Forest Nursery, College of Forestry, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh, India, between July 2019 – October 2019 and July 2020 – October 2020.

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**Methodology:** The research was laid out in Randomized Block Design replicated thrice with twelve treatments *viz*., T1 (Control), T2 (100% Recommended dose of fertilizer), T3 (75%) RDF), T4 (50%) RDF), T5 (75%) RDF + (25%) RDF through FYM), T6 (50%) RDF + (50%) RDF through FYM), T7 (75%) RDF + (25%) RDF through Mustard Oilcake, T8 (50%) RDF + (50%) RDF through Mustard Oilcake and T9 (75%) RDF + (25%) RDF through Vermicompost, T10 (50%) RDF + (50%) RDF through Vermicompost, T11 (75%) RDF + (25%) RDF through poultry manure and T12 (50%) RDF + (50%) RDF through poultry manure. These treatment combinations were applied prior to sowing of maize. After harvesting of maize in October, the said observations i.e. dry matter accumulation and nutrient uptake by maize plant were calculated.
**Results:** In the effect of twelve treatments, T9 (75% RDF + 25% N through Vermicompost) considerably influenced and recorded highest dry matter accumulation and nutrient uptake by maize, followed by T11 during two consecutive years, while T1 (control), where no fertiliser or manure was applied under a poplar agroforestry system, recorded the lowest.
**Conclusion:** by application of vermicompost in combination with chemical fertiliser considerably improved growth characteristics and output. All of the treatments had a considerable impact on maize growth and yield. The optimum result was found to be 75 % RDF + 25 % Vermicompost (T9) in the current study. Our results indicated that, organic fertilizer can be a superior supplement of inorganic fertilizer to produce healthier growth and yield of maize.

*Keywords: Agroforestry; dry matter accumulation; INM; nutrient uptake; soil fertility.*

## 1. INTRODUCTION

Poplar (*Populus deltoides* Bartr.) is a multipurpose fast growing valuable timber species and has emerged as one of the most suitable tree species for agrisilviculture system. It is widely adopted by farmers on a commercial basis and agro-forestry systems based on poplar (*Populus deltoides*) will play an essential role in fulfilling people's economic, social, and environmental concerns. Almost any crop (cereals, pulses, vegetables, forage, fruit/vegetable crops, etc.) can be grown with poplar plantation [1]. Poplar tree plantation is very profitable and cost-effective operation since there is a ready market for its products due to the area's established processing industries (about 1,200 units of all categories in Punjab, Haryana, Delhi, Uttarakhand, Uttar Pradesh, and so on) [2]. The average annual output is 26.14 million tonnes, with a usefulness of 2.43 tonnes per hectare. In India, maize is used for human food (23%), poultry feed (51%t), animal feed (12%), contemporary (starch) goods (12%t), drinks, and seed (1% each). Cultivation of cereal crops such as maize under poplar trees could be a long-term solution for improving soil fertility, increasing cereal crop and poplar tree productivity, and providing financial security to farmers that embrace the method. However, understanding of species compatibility, component arrangement, and nutrient management is required for successful cereal crop development in an agri-silviculture system. Due to its quick growth tendencies, maize is a highly tiring crop, and it is crucial that vital nutrient components are provided in optimum quantities to retain soil fertility and increase production [2].

Because of its enormous production capacity, it is known as the "queen of cereals." It is grown in India on an area of 8.69 million hectares, covering 4% of the net area sown, with annual production and growth of 21.81 million tonnes and 3.6 percent, respectively. Nutrient management by appropriate application of organic sources (FYM, Vermicompost, poultry manures, etc.) and micronutrients is essential to ensure optimal crop output. Furthermore, one of the most critical elements influencing maize crop development and yield productivity is fertiliser management [4]. Chemical fertilisers can alter soil pH, disrupt beneficial microbial ecosystems, increase pests, and possibly contribute to greenhouse gas emissions. In this context, smart use of integrated nutrient management is one of the greatest options for ensuring long-term crop productivity while maintaining soil fertility in maize and other cereal-based cropping systems. This ultimately improves crop yield [1].

The amount of animal excreta and crop wastes available is insufficient to meet the country's crop production needs. As a result, the best option appears to be optimising the use of organic waste and combining it with chemical fertilisers and biofertilizer in the form of integrated manure [5]. Farmyard manure and vermicompost are significant components of integrated nutrient management. Organic manures provide trace

amounts of micronutrients that farmers typically do not provide as straight fertilisers. As a result, organic farming is the sole solution that should be promoted in order to reduce input costs and increase soil health. Organic manures such as FYM and Vermicompost not only help to sustain soil productivity by enhancing the physico-chemical qualities of the soil, but they also aid to improve the efficacy of chemical fertilisers that are applied. It mitigates the negative effects of chemical fertilisers on soil bacteria by lowering chemical toxicity and so promoting their growth. Furthermore, organic manure enhances the soil's water holding capacity and cation exchange capacity, resulting in a consistent supply of nutrients to crop plants and, ultimately, lucrative harvests [6].

According to Chhetri and Sinha [7], the treatment with 75 % RDF + PSB + Azotobacter + vermicompost (VC) @ 5.0 t ha-1 had the maximum N, P, and K uptake, followed by 100 % RDF + PSB + Azotobacter, 100 % RDF, and the treatment with 50 % RDF +PSB+ Azotobacter + 50 % vermicompost had the lowest N, P, and K uptake. Similarly, Ramachandrappa et al. [8] and Meena et al. [9] reported that maize uptake of N, P, and K was increased by applying 75 percent of the prescribed fertiliser dose and 2.7 t ha-1 vermicompost.

The INM approach focuses on preserving plant nutrition supplies in order to maintain a particular level of crop production by combining the profits of all available plant nutrition sources, as appropriate for each crop trend and farming circumstance [10]. Incorporating organic manure into the soil regulates nutrient absorption, promotes development, improves soil quality (physical, chemical, and biological), and has synergistic effects on crops [8]. Any crop's ability to absorb nutrients is mostly determined by the amount of biomass produced by the plant. The accumulation of various nutrients inside the plant system, on the other hand, frequently determines their overall intake [9].

In view of the above, the present experiment was performed with the intention of investigating the benefits of integrated nutrient management in terms of nutrient uptake and dry matter accumulation under poplar-based agroforestry conditions.

## 2. MATERIALS AND METHODS

A two year field experiment was conducted during 2019-20 and 2020-21 at Forest Nursery, College of Forestry, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, India. Prayagraj is arranged at 25.26° N longitude and elevation, 81.54° E longitude and height, and 98 m over the mean sea level. It is situated in Uttar Pradesh's south-eastern corner and has a tropical to subtropical climate with summer and winter seasons. The experiment carried out during kharif, with 12 treatments and three replications on levelled ground *viz*., T1 (Control), T2 (100% Recommended dose of fertilizer), T3 (75%) RDF), T4 (50%) RDF), T5 (75%) RDF + (25%) RDF through FYM), T6 (50%) RDF + (50%) RDF through FYM), T7 (75%) RDF + (25%) RDF through Mustard Oilcake, T8 (50%) RDF + (50%) RDF through Mustard Oilcake and T9 (75%) RDF + (25%) RDF through Vermicompost, T10 (50%) RDF + (50%) RDF through Vermicompost, T11 (75%) RDF + (25%) RDF through poultry manure and T12 (50%) RDF + (50%) RDF through poultry manure. Nitrogen application for FYM, Mustard Oil Cake, Poultry manure and VC were calculated on N equivalent basis of RDF. 100% phosphorus through Single Super Phosphate and potash through Muriate of Potash were applied prior to sowing. Well-decomposed FYM, VC, Poultry Manure and Mustard Oil Cake were added to the plots as per treatment two weeks prior to sowing. MS 2 maize was planted in the first week of July and harvested in the second week of October. During the crop-growing period, four irrigations were administered at important periods of crop growth, and all other recommended packages of practises were followed. The crop was harvested by plucking cobs. Five plants were chosen at random from each plot and tagged to track the effects of different treatments on yield attributes. Urea, Single Super Phosphate, and Muriate of Potash were used to meet maize's nutrient requirements. After harvest, the dry matter accumulation and nutrient uptake of maize were recorded for each treatment, and the data was analysed using statistical software of Randomized Block Design [3].

### 2.1 Soil of the Experimental Field

The soil samples were collected randomly from 0 to 15 cm depth from 5 spots of the experimental field in both the years just before layout of experiment. A representative homogenous composite sample was drawn by mixing all these soil samples together, which was analyzed to determine the physico-chemical properties of the soil. The soil was sandy loam in texture, medium

in organic carbon (0.54%), low in available nitrogen (139.4kg/ha), medium in phosphorus (14.2kg/ha) and potash (158.4 kg/ha).

## 3. RESULTS AND DISCUSSION

### 3.1 Dry Matter Accumulation

The data on dry matter production presented in Table 1 revealed that it was increased steadily with increase in age of the crop from vegetative to harvesting stage.

During the first and second years of analysis, the dry matter accumulation was maximum (175.6 g/m$^2$ and 160.50 g/m$^2$) with (75 %) RDF + (25 %) RDF Vermicompost (T9) and lowest with T1 (control) after 30 DAS of the crop, respectively. T9 (168.0 g/m$^2$) had the highest dry matter accumulation in the effect of varied fertiliser and manure combinations, followed by T11. Furthermore, in successive phases of 60 DAS and at harvest, the treatment T9 (75 % RDF + 25 % N through vermicompost) produced the maximum dry matter, *viz.* 727.1 and 1392.7 g/m$^2$, with the control (T1) producing the lowest value of dry matter in both years and in pooled data. This was due to the higher nutrient availability in case of combined use of organic and inorganic sources of nitrogen than that of treatment without external source of nitrogen in control. As maize is high nutrient requiring crop, addition of 75% of RDF along with vermicompost fulfills its immediate nutritional requirement due to increased solubility of nitrogen and its constant availability throughout the crop period. Moreover, addition of vermicompost increased the organic carbon of the soil which provides a more conducive rhizosphere for maize crop, higher rate of aeration, increased the soil microbial activity as well as mineralisation of nutrients (Sharma et al. [11]). Yadav et al. [10], Samreen et al. [6] and Deewan et al. [5] also reported similar findings, While the lowest dry matter accumulation was recorded under the 50% RDF (T2). The treatment where no nitrogen is applied from any source showed very low dry matter accumulation due to very less nutrient availability from the available soil pool. Ghosh et al. [12] and Bhjarali et al. [13] both reported similar findings.

### 3.2 Nutrient Uptake

#### 3.2.1 Nitrogen uptake

Table 2 shows that the nitrogen uptake by maize was higher with T9 (75 % RDF + 25 % N through vermicompost) in both the years of experimentation and in pooled data. T9 had the highest nitrogen (142.3 kg ha-1 and 154.7 kg ha-1) among fertiliser treatments, which was significantly greater than all other treatments and lowest (79.40 kg ha$^{-1}$ and 98.3 kg ha$^{-1}$) was analysed under control with no fertilizer and manure treatments in consecutive years. T9 treatment, followed by T11, and T1 (88.9 kg ha-1) treatment, which received neither fertiliser nor manure, had the highest N uptake by maize crop in 2019 and 2020, according to pooled data. The higher value of nutrient uptake under T9 is due to higher value of dry matter accumulation as result of constant and steady availability of nitrogen to the maize crop.

Moreover, the addition of leaf litter to the agroforestry system increased accessible nitrogen, according to the findings of the current study. The increase in N content of soil under tree cover was reported by Shaikh and Pinky [14].

The use of organic manure increases the amount of nitrogen available to the crop while also improving the soil's nutritional status. The current investigation's conclusions are consistent with Kumpawat and Rathore findings [15]. Sharma et al. [11] also found that the treatments that received vermicompost or FYM in combination with chemical fertilisers had nitrogen uptake levels than the control.

#### 3.2.2 Phosphorus uptake

The results in Table 2 shows that, the treatments receiving integrated sources of nutrients had a considerable impact on the available phosphorus content of the soil. P content was found to be highest (47.6 kg ha-1 and 51.2 kg ha-1) under T9, which was determined to be considerably higher than all other treatments, whereas, minimum P (20.6 kg ha$^{-1}$ and 29.0 kg ha$^{-1}$) was recorded under T1 during both consecutive years. Pooled data on the effect of fertiliser and manure treatments revealed the similar trend of results, with T9 receiving the highest P uptake (49.4 kg ha-1) and T1 receiving the lowest (24.8 kg ha-1) under control. Addition of organic sources of nutrients enhanced the microbial activity of soil resulting in maximum leaf litter decomposition and thereby increasing the level of accessible phosphorus under poplar Kaushik et al. [16] and Bairwa et al. [17]. The application of integrated source of nutrients produces more organic anions and stimulating microbial activity

**Table 1. Effect of INM on dry matter accumulation (g / m$^2$) of maize crop in maize-poplar based agroforestry system**

| Treatments | Dry matter accumulation (g / m$^2$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 30 DAS | | | 60 DAS | | | At harvest | | |
| | 2019 | 2020 | Pooled | 2019 | 2020 | Pooled | 2019 | 2020 | Pooled |
| $T_1$ | 95.6 | 100.7 | 98.1 | 382.3 | 494.6 | 438.5 | 835.6 | 1027.9 | 931.8 |
| $T_2$ | 151.8 | 145.3 | 148.6 | 595.3 | 618.1 | 606.7 | 1184.4 | 1268.9 | 1226.7 |
| $T_3$ | 97.3 | 126.8 | 112.1 | 524.1 | 552.2 | 528.9 | 1072.9 | 1212.5 | 1142.7 |
| $T_4$ | 96.1 | 123.7 | 109.9 | 499.6 | 503.2 | 501.4 | 840.7 | 1047.8 | 944.2 |
| $T_5$ | 158.3 | 156.2 | 157.3 | 639.6 | 647.4 | 643.5 | 1292.5 | 1315.9 | 1304.2 |
| $T_6$ | 98.7 | 132.1 | 115.4 | 554.3 | 552.4 | 553.2 | 1074.8 | 1220.6 | 1147.7 |
| $T_7$ | 138.6 | 139.1 | 138.9 | 576.1 | 575.0 | 575.5 | 1150.0 | 1261.8 | 1211.0 |
| $T_8$ | 96.9 | 126.4 | 111.6 | 505.3 | 504.7 | 514.4 | 1040.0 | 1127.5 | 1083.8 |
| $T_9$ | 175.6 | 160.5 | 168.0 | 645.2 | 727.1 | 686.2 | 1364.7 | 1392.6 | 1378.7 |
| $T_{10}$ | 131.4 | 138.4 | 134.9 | 565.3 | 567.3 | 566.3 | 1101.5 | 1257.5 | 1205.9 |
| $T_{11}$ | 160.8 | 159.1 | 160.0 | 644.2 | 673.9 | 659.0 | 1334.8 | 1326.5 | 1330.7 |
| $T_{12}$ | 99.4 | 134.5 | 117.0 | 560.5 | 554.1 | 557.3 | 1080.9 | 1256.4 | 1179.5 |
| SEm (±) | 8.5 | 10.5 | 7.8 | 36.1 | 28.4 | 26.4 | 103.4 | 71.1 | 55.6 |
| CD @ 5% | 25.0 | 30.9 | 22.7 | 105.8 | 83.2 | 77.6 | 303.3 | 208.6 | 163.0 |

**Table 2. Effect of integrated nutrient management on Nitrogen, Phosphorus and Potassium uptake (kg ha$^{-1}$) by maize under poplar agroforestry system**

| Treatments | N (kg ha$^{-1}$) | | | P (kg ha$^{-1}$) | | | K (kg ha$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | **2019** | **2020** | **Pooled** | **2019** | **2020** | **Pooled** | **2019** | **2020** | **Pooled** |
| $T_1$ | 79.4 | 98.3 | 88.9 | 20.6 | 29.0 | 24.8 | 140.0 | 149.7 | 144.9 |
| $T_2$ | 121.5 | 142.9 | 132.2 | 46.2 | 47.3 | 46.8 | 181.5 | 212.9 | 197.2 |
| $T_3$ | 106.5 | 112.0 | 109.3 | 34.0 | 39.6 | 36.8 | 160.9 | 189.3 | 175.1 |
| $T_4$ | 81.1 | 98.6 | 89.8 | 30.8 | 34.4 | 32.6 | 155.9 | 170.6 | 163.3 |
| $T_5$ | 132.5 | 146.3 | 139.4 | 46.3 | 47.4 | 46.8 | 194.9 | 213.7 | 204.3 |
| $T_6$ | 110.9 | 122.0 | 116.4 | 36.4 | 41.3 | 38.9 | 164.5 | 198.5 | 181.5 |
| $T_7$ | 120.0 | 140.5 | 130.3 | 40.6 | 43.2 | 41.9 | 181.3 | 210.6 | 196.0 |
| $T_8$ | 106.3 | 105.3 | 105.8 | 32.0 | 37.5 | 34.7 | 156.0 | 188.4 | 172.2 |
| $T_9$ | 142.3 | 154.7 | 148.5 | 47.6 | 51.2 | 49.4 | 222.8 | 221.6 | 222.2 |
| $T_{10}$ | 114.0 | 137.8 | 125.9 | 40.3 | 42.4 | 41.4 | 176.2 | 204.4 | 190.3 |
| $T_{11}$ | 138.9 | 147.0 | 142.9 | 47.4 | 49.4 | 48.4 | 215.6 | 219.7 | 217.7 |
| $T_{12}$ | 113.5 | 130.3 | 121.9 | 39.8 | 42.0 | 40.9 | 171.3 | 203.8 | 187.5 |
| SEm (±) | 8.8 | 9.8 | 6.2 | 3.9 | 4.1 | 2.5 | 13.7 | 14.2 | 8.7 |
| CD @ 5% | 25.8 | 28.8 | 18.2 | 11.4 | 11.9 | 7.3 | 40.3 | 41.5 | 25.6 |

resulting in increased phosphorus availability and its uptake by crop. Similar outcomes were also reported by Chandrakala et al. [18] and Priya et al. [19].

### 3.2.3 Potassium uptake

The maximum K content (222.8 kg ha-1 and 221.6 kg ha-1) was recorded under T9, which was found to be substantially higher than all other treatments followed by T11 (215.6 and 219.8 kg ha-1). Whereas the minimum K content (140.0 kg ha-1 and 149.8 kg ha-1) was observed under T1 over both consecutive years (Table 2). Pooled data of 2019 and 2020 revealed similar trend of maximum Potassium in T9 (222.2 kg ha-1) followed by T11 (217.7 kg ha-1) and minimum (144.9 kg ha-1) in T1 where no fertilizer and manure were given.

Potassium (K) is an important mineral for plant growth and is classified as a macronutrient since plants absorb large amounts of it throughout their lifetimes. The potassium content of soil beneath a poplar tree canopy was higher than that of a single maize crop due to the addition of organic matter in the soil in the form of leaf fall and tree root density. The findings are consistent with [20] and [17].

The potassium content of the soil was dramatically improved after using organic

manures. The addition of more organic manure may have aided in the conversion of inaccessible free potassium to available form in the soil solution, increasing the soil potassium concentration. The available K levels in vermicompost-treated soil were greater than in control soil due to higher microbial activity. Vermicompost application increased the available K, according to Davari et al. [21]. Aula et al. [22], Chandrakala et al. [18], and Rana et al. [23] also found similar results.

Dry matter accumulation and nutrient content in plant parts are the primary determinants of nutrient uptake by a crop. So higher value of dry matter accumulation in T9 increased the K uptake in maize. Kumari et al. [24] also found that combining inorganic and organic fertilizers resulted in increased NPK uptake in maize.

## 4. CONCLUSION

Based on the results of this study, it can be concluded that using vermicompost in combination with chemical fertilizer considerably improved the dry matter accumulation and nutrient uptake by maize crop. The optimum result was found to be 75 % RDF + 25 % Vermicompost (T9) in the current study. Our results indicated that, fertilizers should be applied in combination with organic manure (vermicompost) for better growth, nutrient uptake by maize and to improve soil characteristics in poplar based agroforestry system. This kind of nutrient management reduces waste, enhances nutrient efficiency and is eco-friendly with a potential to get optimum production.

## ACKNOWLEDGEMENTS

I am thankful to Dr. Antony Joseph Raj, Dean, College of Forestry, SHUATS, Prayagraj, Uttar Pradesh who provide all assistance in doing my research work and also indebt my gratitude to Hon'ble Vice Chancellor, and Dean, Extension Education, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha sending me for higher study.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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